ACTA GEOGRAPHICA SZEGEDIENSIS
Tomus XXXVIII (2004)
http://www.geo.u-szeged.hu/acta

INVESTIGATIONS ON THE RATE OF FLOODPLAIN SEDIMENT ACCUMULATION IN THE MÁRTÉLY EMBAYMENT OF THE LOWER TISZA

KISS, Tímea – SÁNDOR, Andrea – GRESÓ, Zsolt

Introduction

Recently, floods with record-breaking highs are encountered in the river Tisza more and more frequently. Usually, several factors, acting either separately or collectively reinforcing each other, are blamed for contributing to these extraordinary floods such as (SZLÁVIK, 2001; SOMOGYI, 2000; RAKONCZAI, 2000):

- Changes in the landscape utilization of the active floodplains, as well as general landscape planning in the watershed area.
- The spatial and temporal alterations in the quantities and intensities of rainfall.
- The gradual silting-up of the active floodplain.
- The water retaining effect of the tributaries and the river Danube
- The low gradient of the river and the irregularity of the riverbed.
- The changing distances between the dikes on the banks along the course.
- The unexpected side-effects from the use of out of the country reservoirs.
- The increase in paved surfaces.

The present work is restricted to the analysis of a single factor of the above mentioned ones, namely the possible effects of the general silting-up of the active floodplain in the creation of these increasingly higher level floods, and the determination of the amount of sediment, which have accumulated on the active floodplain since the river controlling works of the 19th century. The Mártély embayment of the Lower Tisza region was chosen as the pilot area of our investigations. The degree of sediment accumulation and silting-up was recorded at two sites: (1) a morphological feature of known age acting as a reference (2) a site on the active floodplain always known to be exclusively a part of the floodplain.

Preliminaries

More and more workers are engaged in studying the geological processes of the active floodplain of the river Tisza and its tributaries, including the degree of sediment accumulation on and silting-up of the active floodplain, using various methods and approaches. According to calculations done by KÁROLYI (1960), in places lacking active channel displacement and cutoffs point bars are in a relatively elevated position being located sometimes even 2 m higher than the adjacent areas. Meanwhile, silting-up in the narrow active floodplains can reach even higher degree, an increase of 0.3-1.6 m.

Analyzing a digital elevation model of the Tisza catchment area, GÁBRIS et al. (2002) inferred a 0.23-0.6 m sediment accumulation rate in the reach between the mouth of the Sajó and Tiszadob from the time of the 19th century river regulations. SZLÁVIK (2001), utilizing hydrological records, could successfully quantify the degree of silting-up observable on the active floodplain, the littoral parts and the point bars in the Middle and Upper Tisza region. According to the recorded values, the average annual sediment accumulation on the active floodplain of the Lower Tisza was 1 cm for the period between 1976 and 1983. The same value was 5 cm for the areas of the point bars and the 30-50 m wide near-bank areas, though occasionally even annual deposits with a thickness of 60-80 cm were also recorded on the point bars.

Direct sediment accumulation measurements were carried out in the area of the Szatmár Lowlands by BORSY (1972), on the active floodplain of the Szamos, after the cessation of the 1970 spring floods. According to his observations, the largest rate of sediment accumulation was restricted to the areas adjacent to the banks (0.2-0.3 m). There was a rapid drop in the thickness of the accumulated deposits at successively larger distances from the riverbed, while the presence of only a thin coating could have been identified at the foot of the artificial levees.

SCHWEITZER using various sedimentological tools and methods managed to quantify the degree of sediment accumulation on the active floodplains of the river Körös and the Middle Tisza region. According to his findings, the floodplain was heightened by about 1.6-1.8 m in the vicinity of Békésszentandrás from the time of the 19th century river regulations (SCHWEITZER, 2001). While recently, a unique 10 cm/flood sediment accumulation rate could have been inferred for a point bar in the Tisza near Szolnok (SCHWEITZER et al., 2002). According to NAGY et al. (2001), there was a silting up of 1-1.5 m in certain narrow active floodplains of the Middle Tisza region from the time of the river regulations. However, in case of an active point bar the ratio of sediment accumulation can be even as high as 10-45 cm during major floods.

KISS et al. (2002) determined the average thickness of the sediments accumulated in the Lower Tisza between 1998 and 2001 to be 2 cm, pointing out that sediment accumulation on the point bars could have reached even higher rates during this time (0.7 m). Though, this value was only 1-5 cm in the 10-20 m wide near-bank areas.

The study area

The pilot area of our work is situated on the left banks of the river in the largest floodplain embayment of the Lower Tisza region, NW of the city of Hódmezővásárhely, between the 209.5 and 198 fluvial kms (**Fig.1.**), in the area of the Mártély Natural Preserve. The dikes in the study area were constructed in 1882 followed by a cutoff of the channel in 1889 (Ányás-Mártély) (IHRING, 1972). After the regulations, the length of the Ányás bend was shortened to 2.6 km from the original 5.4 km. While the original 1.5 cm /km gradient increased to 2.5 cm/km (LÁSZLÓFFY, 1982).

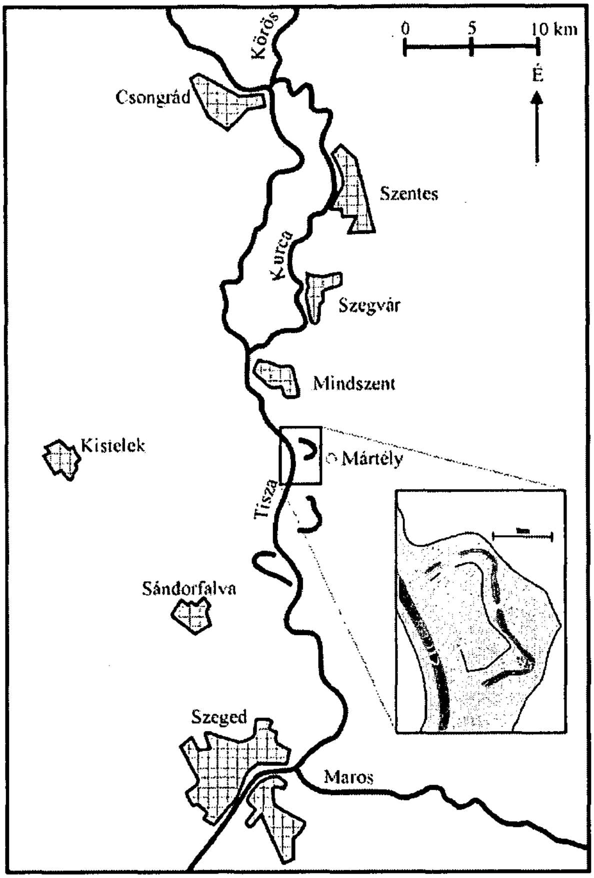

Figure 1. The location of the study area

Samples were collected from the Ányás island, bordered by the river Tisza and the Dead Tisza of Mártély. Here, the 850-2600 m wide active floodplain is located at 78-82 m ASL. Remnants of the ancient dike system, as well as numerous point bars and natural levees are elevated above the floor of the flat embayment (**Fig. 2.**).

The highest floodwaters (1000 cm) affecting the study area were recorded during the spring of 2000 in the Mindszent floodometer. Low waters are restricted to the fall and winter parts of the year, with the lowest values (-280 cm) recorded in October 1946. In a normal year floodwaters tend to cover sometimes even as wide as 4 km areas of the Mártély embayment, seemingly reflecting the original conditions, which might have prevailed on the floodplain preceding the 19th century river regulations. The area of the Ányás island, located between the dead arm of Mártély and the Tisza are generally covered by planted stands of poplar and mixed oak woodlands. Occassionally even the oldest stands were preserved in some areas as well as abandoned orchards and wetlands, offering ideal habitats for various species (RAKONCZAY, 1987).

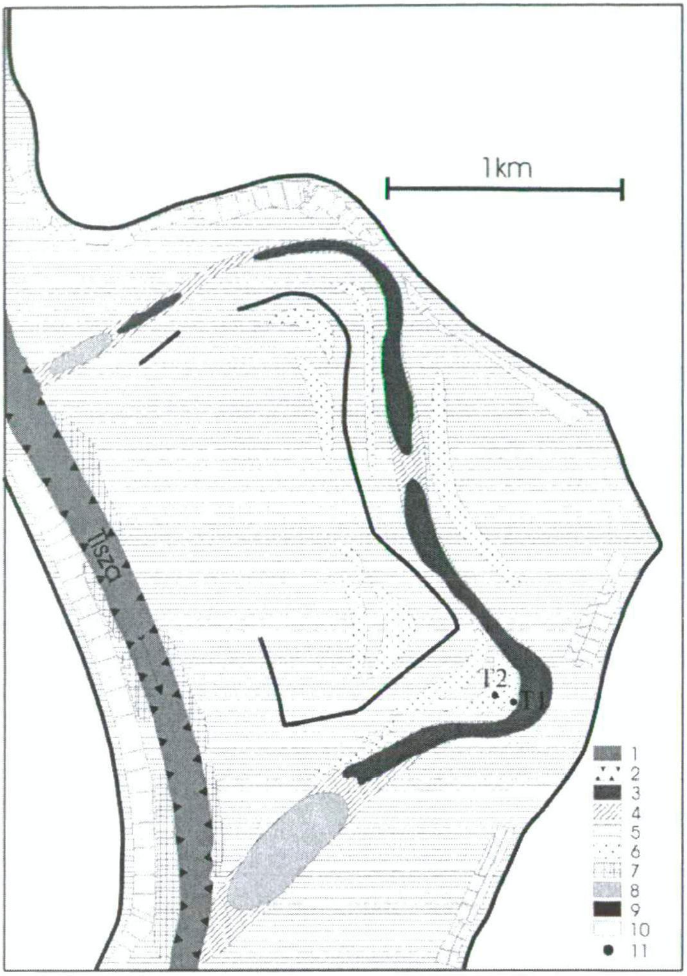

Figure 2. The geomorphological map of the studied area with the location of the sampling sites marked

1: modern active riverbed, 2: river cliff, 3:formerly active riverbed, 4: formerly active riverbed with water coverage, 5: alluvium, 6: former point bar, 7: near-shore bar, 8: point bar, 9: dike, 10: earthwork ditch, 11: sampling site

Material and methods

Two test pits were dug in the study area. One of these (T1) is located on the right banks of the cutoff channel of Mártély, corresponding to the inner convex sandy side of the former river bend of the Tisza; the other pit (T2) is located on the active floodplain between the cutoff channel and the active riverbed. Samples were collected at 2 cm intervals. As the goal was to infer the thickness of sediments accumulated since the river regulations, the T1 pit was deepened and sampled only to the horizon of the sandy beds, which must correspond to the point bar deposits of the formerly active riverbed preceding the regulations.

Accordingly samples from the T2 pit were taken to a depth of only 1 m, as no larger sediment accumulation rates could have been presumed for the higher parts of the active floodplain on the basis of observations made at T1.

The collected samples were subjected to grain-size analysis using the Köhn type pipette method and dry sieving. The grain-size classes were determined after Mihåltz. The carbonate content of the samples was measured by Scheibler-type calcimetry. After pretreatment with potassium bichromate, the organic content was determined by spectrophotometry. The collected samples were also subjected to heavy metal analysis for the elements of Cd, Ni, Zn, Cu, Pb after total digestion with aqua regia using an AAS type Perkin Elmer 3110. The values received are given in ppm. Samples from T2 were subjected to magnetic susceptibility studies in the SAS laboratory of the University of Wolverhampton using a device type Bartington MS2B. The final results were graphically depicted using the software packages TILIA and TILIA Graph. During the course of evaluation, ratio of sediment accumulation in the pit deepened in the inner parts of the active floodplain (T2) was determined on the basis of the results of the reference samples of T1 taken from a morphological unit of known age.

Results

1. The timing and length of floods between 1901-2001

Via utilizing the hydrological data of the ATIVIZIG for the period of 1901 and 2001, the highest water level values (HWV) as well as the intra-annual extent of flooding and water cover in the floodplain was studied in details. The utilized data were all recorded on the floodometer of Mindszent, located closest to the study area of Mártély. For the determination of the length of flooding two water levels were taken into account: (1) the river tends to leave its course at a water level of 520 cm; the forms of the floodplain are not univocally covered by water until the level of 630 cm; (2) at levels exceeding 630 cm the point bars and even the highest parts of the floodplain become flooded as well. The profile of T2 is located at 80 m ASL on the active floodplain, while that of T1 occupies a formerly active point bar, preceding the river regulations, at 79 m ASL. Consequently, the area of T1 must have experienced more and longer-lasting flooding than that of T2 (**Fig. 3.**). Via using the HWV and the values of the intra-annual extent of flooding on the active floodplain 6 major floods could have been identified for the past 100 years in the study area, on the basis of the prevalence of short-term or long-term flooding (**Table 1.**).

2. The description of the individual profiles

A. The profile corresponding to the formerly active point bar (T1)

The inner convex sandy side of the former river bend of the Tisza is located closer to the cutoff channel and must have experienced longer water coverage during the floods located 1 m below the horizon of the inner parts of the active floodplain, where the other profile was created (about 79 m ASL). The profiles were divided into zones and units, with samples having similar features grouped into a single zone (**Fig. 4.**).

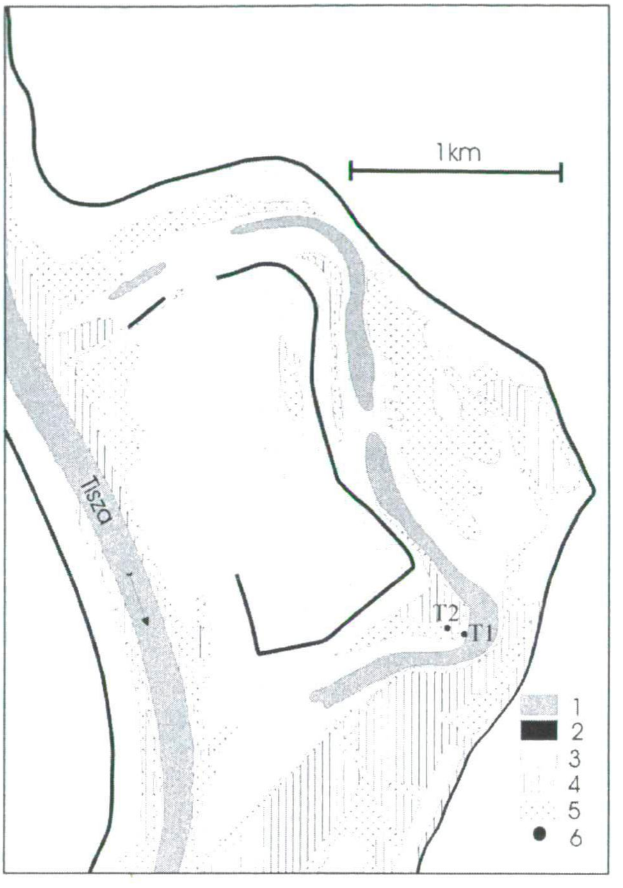

Figure 3. The elevation characteristics of the study area
1: water, 2: dike , 3: <79m, 4. 79.5-80.5m, 5: >80.5m, 6: sampling site

Table 1. The characteristics of the inferred flood periods with the highest recorded water level values (HWV) marked

Period	Length	The duration of floods (above the water level of 630 cm)		HWV cm (year)
		Within the period (%)	During the year with the longest extent of flooding (%)	
1.	1912-1919	14	23.5 (1916)	951 (1919)
2.	1922-1926	8	14.8 (1924)	910 (1924)
3.	1940-1945	25	40.27 (1941)	974 (1944)
4.	1962-1970	9	30.4 (1970)	982 (1970)
5.	1974-1981	13	15.6 (1979)	892 (1981)
6.	1998-2001	13	21.1 (1999)	1000 (2000)

Zone I. (88-94 cm):

In these samples the highest sand values were recorded (above 90%), implying that this material must correspond to the deposits of the formerly active point bar, preceding the 19th century river regulations. In order to back up this assumption, grain-size composition of samples taken from a modern active point bar at Mindszent was also determined and compared. There the recorded total sand fraction was around 92. 2%, which seems to be congruent with the value received for the lowermost part of the T1 profile. Minor peaks of Cd and Ni could have been identified in this zone between the depths of 90-92 cm.

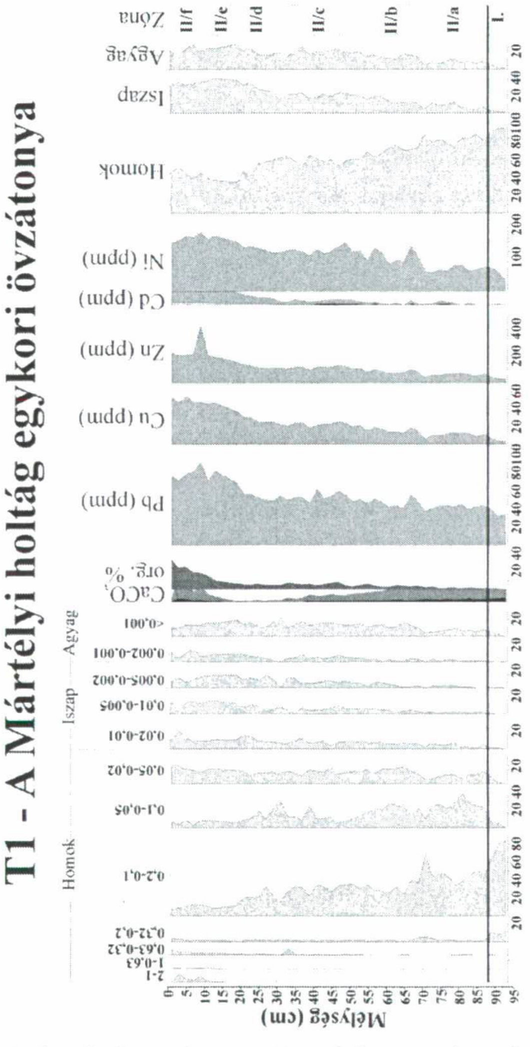

Figure 4. The chemical and physical properties of the samples taken from the profile created on the former point bar of the Mártély cutoff channel (T1)

Zone II. (0-88 cm):

This zone from a depth of 88 cm upwards must represent the material, which accumulated after the river regulations of 1889. The sequence is upward fining, with a gradual upward decrease in the sand content, accompanied by an increase in the silt and clay content. This zone was further subdivided into units or subzones on the basis of marked changes in the general sedimentary features.

In unit II./a (70-88 cm) the sand content goes below 90%, but the dominant sand fraction is alternating with the depth (e.g. very fine sands are 52.8% between 84-86 cm; fine sands are 37.8% between 80-82 cm etc.) The total amount of silt and clay in these layers is around 20%. The lowermost boundary of this unit was determined by the clearly observable peak of all five heavy metal elements (86-88 cm). While an increase in the sand fraction (approx. 90%) marks the uppermost boundary of this unit between the depths of 70-72 cm. The four major peaks in fine and medium sands must correspond to the major floods between 1912-19.

The generally decreasing trend in the sand content is observable in unit II./b (54-70 cm) as well. Although there are two major peaks observable in the sand content between 54-56 cm and 62-64 cm (76.8% and 69.2%, respectively), attributable to an increase in the medium, fine and very fine sands in the layers. These two peaks must correspond to the two largest floods of the period between 1922 and 1926. There is an increase in the silt and clay content with relatively high values between the depths of 56-58 cm (> 15%). This also holds for samples taken from the depths of 64-66 and 66-68 cm as well. These samples with a higher clay and silt content are all characterized by high values of all studied heavy metal elements. Conversely, only three elements have high values (Pb, Cd, Ni) between the depths of 62-64 cm.

In the samples of unit II./c (30-54 cm) three major sand peaks could have been identified between the depths of 32-34, 38-40 and 44-46 cm, respectively. Here the sand fraction exceeds 60% in the samples with a dominance of fine and very fine sands. The floods between 1940-1945 seem to correspond to this part of the section. Similarly three major peaks with values exceeding 20% can be observed in the silt and clay content in this part of the profile (36-38 cm, 46-48 cm, 52-54 cm). In these samples there is an increase in the amounts of Pb, Cu, Zn, plus that of Ni in the sample taken from a depth pf 52-54 cm.

The upward fining trend is also observable in unit II./d (20-30 cm) where the sand fraction is below 50% in samples between 20-22 and 22-24 cm. Several minor peaks in the sand content are observable in this part of the profile, which must correspond to numerous floods between 1962 and 1970. The peak values of silt and clay were recorded between the depths of 22-24 cm (clay 22.7%, silt 35%) with a concomitant increase in the amount of Pb, Cu and Ni.

A relatively peaceful period characterizes the next unit of II./e (10-20 cm) (1974-81?) without any outstanding values in the sand, silt or peak contents. However, there is an upward increase here in the sand content, accompanied by a decrease in the clay content.

The ratio of the sand and silt is around 35-40% while that of the clay is below 30%. However, all studied heavy metal elements have high values at the depth of 12-14 cm with the exception of Zn.

In the final unit of II./f (0-10 cm) there is an upward increase in the coarse and medium sands (8-10, and 2-4 cm, respectively), probably marking the record high floods from 1998. Here the total silt content manages to remain above 30%. While there are two major peaks in the clay content (0-2 cm and 6-8 cm, respectively). All studied heavy metals tend to have a peak value in the layer between 8-10 cm. This seems to be congruent with the findings of the study of NAGY et al. (2001) in the Middle Tisza region, where also an increase in the Zn and a dual peak of Pb was recorded in the uppermost samples, just like in our case.

B. The active floodplain profile (T2)

The next profile is located in the inner parts of the active floodplain (**Fig. 5.**), approximately 1 m higher than the T1 profile. Consequently, this area was affected by floods with water levels higher than 630 cm only. So the amount of sediments, which accumulated after the river regulations, must be also lower here. In case of the T1 profile, the actual thickness of deposits, which accumulated after the river regulations, can be determined with high accuracy as we are dealing with a geomorphological feature of known age. Conversely, these works by no means result significant alterations in the grain-size composition in the inner parts of the active floodplain, as is the case with the T2 profile. In order to elucidate the accumulated sediments for the past more than 100 years, the marker zones or units identified in the profile of T1 have been utilized for correlation.

On the basis of its grain-size composition and general heavy metal content the T2 profile can be divided into two major units or zones:

Zone I. (32-100 cm):

The deposits of this zone are characterized by a high sand content, relatively low heavy metal and organic content, and also high carbonate content. The concentration of magnetic minerals is also low here with a dominance of coarse grained MD ferromagnetic grains and a significant paramagnetic mineral fraction.

In the lowermost sample of unit I./a (94-100 cm) the proportions of all three grain-size fractions (sand, silt, clay) exceed 30%, with a dominance of the clay fraction (37%).

There is an increase in the sand content to 65% in the uppermost sample of the unit (94-96 cm), with a dominance of fine sands (> 35%). The proportions of clay and silt are below 20% here. The highest amount of Pb, Cu, Ni, Zn were recorded in the lowermost sample (98-100 cm) with a general upward decreasing trend in the horizon. However, no traceable amounts of Cd could have been identified in this unit.

In unit I./b (68-94 cm) the proportion of sand in the samples is high (almost always exceeding 75%), with peak values in samples taken from the depths of 72-74, 82-84 and 92-94 cm, respectively. Conversely, there is an increase in the amount of clay and silt in the samples deriving from the depths of 68-70 and 78-80 cm, with a concomitant peak in the recorded heavy metals as well.

The proportion of sand in the samples of unit I./c (48-68 cm) is also very high (around 90%), with a significant proportion of fine sands between the depths of 50-52, 54-56, 58-60 and 62-64 cm, respectively. Very fine sands have a value of 20% in three samples deriving from the depths of 56-58, 60-62 and 66-68 cm. From the heavy metals, only Cu and Zn were present in measurable proportions, plus Ni in two additional cases.

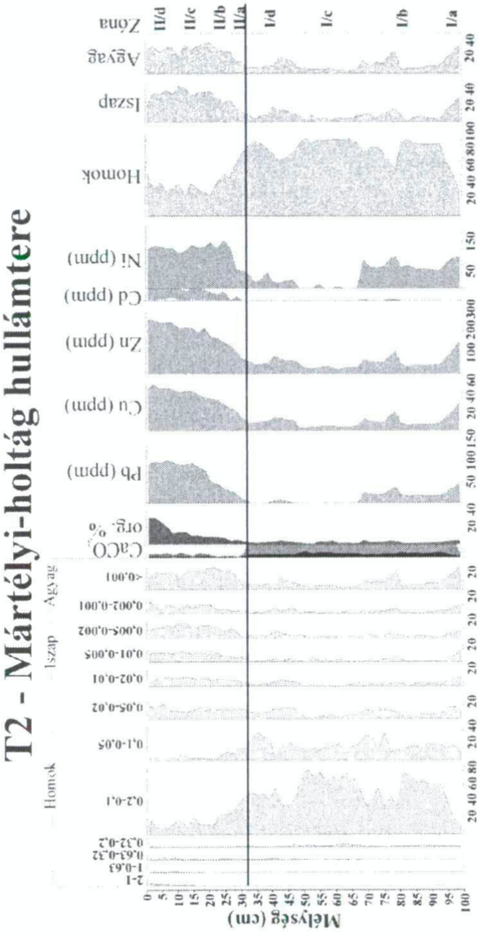

Figure 5. The chemical and physical properties of the samples taken from the profile created on the active floodplain (T2)

In the lowermost part (40-48 cm) of unit I./d (32-48 cm) there is a decrease in the sand content with a concomitant increase in the silt and clay (20-20%), as well as heavy metal content of the deposits (40-42 and 42-44 cm). Then in the samples between 32-40 cm, there is another increase in the sand content with a peak value recorded at 34-36 cm (89%). Cd was not traceable here. Pb was measurable only in three samples. The high carbonate content accompanied by a low heavy metal and psephite content marked the uppermost boundary of this unit and Zone I as well.

Zone II. (0-32 cm):

Here, there is a significant increase in the clay and silt content, concomitantly with a remarkable rise in the amount of the heavy metals as well. In parallel, the proportion of sands and carbonates in the sample experienced a major drop.

There is a gradual decrease in the sand content in unit II./a (28-32 cm), with a still impressive proportion exceeding 60%, and a concomitant increase in the silt and clay content in the samples. The heavy metals also experience a rise here with a maximum of the element of Cd only in this unit between 28-30 cm. On the basis of these features, this unit can be correlated with the II/a unit of the T1 profile.

There is a further decrease in the sand content in unit II./b (20-28 cm) as well with one peak value recorded between 24-26 cm (51%). This is accompanied by a steady increase in the proportions of clay and silt in the samples with two peaks recorded between 20-22 and 26-28 cm, respectively. In the second case both fractions are above 35% in the sample. The heavy metals also experience a further rise with two maximum values of Ni recorded between the depths of 20-22 and 24-26 cm, respectively. The barely noticeable peaks of Pb, Cu and Zn assumes a correlation of this unit with the units of II./b and II./c of the T1 profile. The concentrations of magnetic minerals in units II/a-b are also low . However, there is a gradual increase in the ARM/χ and χ_{ARM} values of the samples. In unit II./c (10-20 cm) the clay and silt content is high, above 60%. There are two increases in the sand content in samples taken from the depths of 10-12 and 14-16 cm. However, it always remains below 40%. The amount of the heavy metals is outstanding for almost all studied elements between 14-16 cm. Zn has peak values even in the lowermost samples of this unit as well (18-20 cm). Similarly high values were recorded in the II/d unit of the T1 profile.

There are two peaks in the sand content in unit II./d (0-10 cm) preceded by peaks of the finer fractions, just like in the uppermost two units of T1. Similar high values of the studied heavy metals (Pb, Cu, Ni, Cd, Zn) were recorded in the lowermost samples of this unit as in those of the II/e unit of T1, connected to floods between 1974 and 1981. During the first half of the 1990s, this area was free of floods, due to the low maximum level of the floodwaters, which prevented sediment accumulation in this part of the active floodplain during the inferred time period (1990-1995). In the uppermost samples of this horizon the studied heavy metals are present also in peak amounts, except for Cd, as in the II/f unit of T1. So these layers must have been deposited after 1998. Units II/c-d are also characterized by outstanding magnetic susceptibility values as well (χ, SIRM, SIRM/χ).

Summary of results

The following general conclusions can be made in connection with the two studied profiles:

1. As the area of the T2 site experienced shorter water coverage and less flooding events than that of T1, the accumulation of fluvial deposits was also lower there. Conversely, the area of the T1 site, experiencing flooding almost every single year must have been the site of greater sediment deposition.

The amount of sediment accumulation from the time of the 19th century river regulations was 88 cm at the T1 site and 32 cm at the T2 site, respectively. This assumption is also justified by the altered magnetic susceptibility of the uppermost samples of the T2 profile (0-32 cm), reflecting intensified soil erosion in the watershed area, as well as intensive accumulation (OLDFIELD 1991).

2. The calculated annual rate of sediment accumulation in the T1 profile after 1889 was 0.79 cm/ year. While it was only 0.29 cm/ year in case of the T2 site.

3. The presence of outstanding coarse grained fractions in the profile served as clear indicators of record high floodwaters and long-lasting flooding events.

References

BORSY, Z. (1972) Üledék- és morfológiai vizsgálatok a Szatmári-síkságon az 1970. évi árvíz után. Földrajzi Közlemények Vol. 41. 87-101.

GÁBRIS, GY. – TELBISZ, T. – NAGY, B. – BELARDINELLI, E. (2002) A tiszai hullámtér feltöltődésének kérdése és az üledékképződés geomorfológiai alapjai. Vízügyi Közlemények Vol. 84. 305-322.

IHRIG, D. (szerk.) (1973) A magyar vízszabályozás története. Budapest 398.

KÁROLYI, Z. (1960) A Tisza mederváltozásai – különös tekintettel az árvízvédelemre. VITUKI 102.

KISS, T. – SIPOS, GY. – FIALA, K. (2002) Recens üledékfelhalmozódás sebességének vizsgálata az Alsó-Tiszán. Vízügyi Közlemények Vol. 84. 456-472.

LÁSZLÓFFY, W. (1982) A Tisza. Akadémiai Kiadó Bp. 610.

NAGY, I. - SCHWEITZER, F. - ALFÖLDI, L. (2001) A hullámtéri hordalék-lerakódás (övzátony). Vízügyi Közlemények vol. 83. 539-564.

OLDFIELD, F. (1991) Environmental magnetism – a personal perspective. Quaternary Science Reviews Vol. 10. 73-85.

RAKONCZAI, J. (2000) A környezet-átalakítás hidrogeográfiai összefüggései az Alföldön. In: Pálfai I. (szerk.): A víz szerepe és jelentősége az Alföldön. A Nagyalföld Alapítvány Kötetei 6. 16-26.

RAKONCZAY, Z. (szerk.) (1987) Kiskunságtól a Sárrétig. A Dél-Alföld természeti értékei. Bp. 195-209.

SCHWEITZER, F. – NAGY, I. – ALFÖLDI, L. (2002) Jelenkori övzátony (parti gát) képződés és hullámtéri lerakódás a Közép-Tisza térségében. Földrajzi Értesítő Vol. 51. 257-278.

SCHWEITZER, F. (2001) Társadalom és a környezet: Gátépítés vagy hullámtérbővítés. In: Keményfi R. –Ilyés Z. (szerk): A táj megértése felé. Debrecen 95-103.

SOMOGYI, S. (szerk.) (2000) A XIX. század folyószabályozások és ármentesítések földrajzi és ökológiai hatásai. MTA Földrajztudományi Kutatóintézet Bp. 302.

SZLÁVIK, L. (2001) A Tisza-völgy árvízvédelme és fejlesztése. Magyar Földrajzi Konferencia, Szeged CD-kiadvány

Vízrajzi Évkönyvek. VITUKI Felszíni Vizek Osztálya

This work was supported by National Research Fund (OTKA) Grant F 037414.

KISS, Tímea Phd
SÁNDOR, Andrea
GRESÓ, Zsolt
University of Szeged, Faculty of Sciences
Department of Physical Geography and Geoinformatics
Egyetem u. 2-6. H-6701 Szeged, P.O.B. 653. Hungary
kisstimi@earth.geo.u-szeged.hu