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CONSTRAINING THE AGE OF FLOODPLAIN LEVELS ALONG THE LOWER SECTION OF RIVER TISZA, HUNGARY

György Sipos*, Tímea Kiss, Orsolya Tóth

Department of Physical Geography and Geoinformatics, University of Szeged, H-6722, Egyetem u. 2-6, Hungary
*Corresponding author, e-mail: gysipos@geo.u-szeged.hu

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Abstract

During the Late Pelistocene-Holocene transition the fluvial landscape of the Great Hungarian Plain changed considerably as a consequence of tectonic, climatic and geomorphological factors. Geochronology, and especially luminescence dating, is a very important tool in reconstructing these changes. The present study focuses on the Lower-Tisza region and addresses the timing of the development of different floodplain levels. In the meantime the luminescence characteristics of the investigated alluvial sediments were also assessed, with a special emphasis on the comparison of silty fine grain and sandy coarse grain results, as in the given medium and low energy environment fine grain sediments are more abundant, however, based on the literature, coarse grain samples are more reliable in terms of luminescence dating. Measurements were performed on 12 samples originating from the point bars of two large palaeo-meanders, representing different floodplain levels along the river. Results indicate the applicability of both grain size fractions for dating purposes, though fine grain subsamples overestimate in average by 1.5 ka the ages yielded by coarse grain subsamples. Consequently, fine grain samples can be used for outlining only general trends, and results need to be controlled by coarse grain measurements where possible. Based on the ages received, the upper floodplain was actively formed until 13-15 ka, when incision and the development of an intermediate floodplain level started. The meander on the intermediate flood plain level developed then very actively until 9 ka. As indicated by the received age information the intensity of meander formation could be highly affected by climatic and especially vegetation control. However, reconstruction can be refined later by further sampling and the application of the results of the present paper.

Keywords: OSL, alluvial sediments, River Tisza, palaeo-fluvial record

INTRODUCTION

The primarily alluvial environment of the Great Hungarian Plain hosts numerous generations of palaeochannels which developed in response to highly varying water and sediment discharges during the Late Pleistocene and Holocene (Gábris and Nádor, 2007; Kiss et al., 2015). In several cases these channels are located on well identifiable floodplain levels, referring to incision governed by either tectonic or climatic processes. The evolution of the fluvial network, and especially the development of the Tisza has been addressed by several earlier studies (e.g. Somogyi, 1967; Gábris, 1986; Borsy, 1989, Kiss et al., 2013), focusing on its palaeo-discharge, pattern changes or the age of certain channel generations.

A key question of fluvial development along the Lower Tisza, affected by tectonic subsidence (Nádor et al., 2007), is the morphology and separation of different floodplain levels. Kiss and Hernesz (2011) and later Kiss et al. (2012) identified two separate levels: a higher and a lower floodplain. The later has several meander cores or umlaufbergs being the remnants of the pre-incision floodplain surface. Based on optically stimulated luminescence (OSL) data, they put the start of incision earlier than 20.1±2.1 ka and the termination of it to 8-9 ka. More recently by extending the morphological analysis to the Serbian section of the river Hernesz (2015) separated a further, intermediate floodplain level as well. The dating of palaeochannels on these floodplain levels was carried out by using OSL on coarser sand sized, but also on fine grain silty sediments, however the comparability of results has only been partly assessed (Hernesz, 2015).

A major underlying principle of OSL dating is that sediment grains during transportation are exposed to sunlight, which resets the OSL signal to zero. Consequently, during laboratory measurements the time elapsed since the last exposure to light, or in other words the time of deposition can be determined. In certain sedimentary environments however resetting is not always complete, which results in partial bleaching, making measured OSL ages higher than the true age. Fluvial deposits are greatly affected by the phenomenon.

Previously, several researches addressed the role of grain size in the bleaching process (Hu et al., 2010; Vandenberghe et al., 2007; Alexanderson, 2007). Most of them concluded that coarser grains (sand) are more suitable for luminescence dating than finer grains (silt), as resetting is more adequate in their case. This is explained by the possible coagulation of fine grains (Hu et al., 2010) and the more frequent exposure of coarser grains on bar surfaces (Rittenour, 2008).

The most common minerals used for OSL dating are quartz and feldspar. Although both minerals are applicable, the choice depends on various factors. Quartz saturates at lower doses, but on the other hand feldspars suffer from anomalous fading (Vandenberghe, 2004). In summary most of the researches emphasize that in terms of fluvial sediments with an age up till several 10 ka the most confident luminescence ages can be received if coarse grain quartz is applied (Bøtter-Jensen, 2006).

The primary aim of the present research was to investigate the development time of two floodplain levels along Lower Tisza by using OSL. Another goal was to assess the rate of morphological evolution in case of the studied palaeomeanders, which provides valuable additional information on the environment in which they were developing. Furthermore, the investigations also allowed to test the luminescence characteristics of alluvial sediments in the region and to compare ages retrieved from the fine grain and coarse grain fraction of OSL samples, since in many situations, as a consequence of the medium energy environment only silty sediments are available for dating.

STUDY AREA

Our research focused on the Lower Tisza Basin where palaeomenaders remained recognizable only in a relatively narrow N-S belt along the Tisza River (Fig. 1). The width and wavelength of these channels significantly exceed contemporary values even if compared to that of the Danube. Two major channel generations were investigated (Fig. 2): one located on the higher floodplain level (Site1), having larger but more blurred pointbars and main channel (meander wavelength=25 km, width=1000 m), and another lying on the intermediate level (Site 2), being smaller but having much intense forms (meander wavelength=9.2 km, width=500 m). The elevation difference is around 1 m between the two floodplain levels.

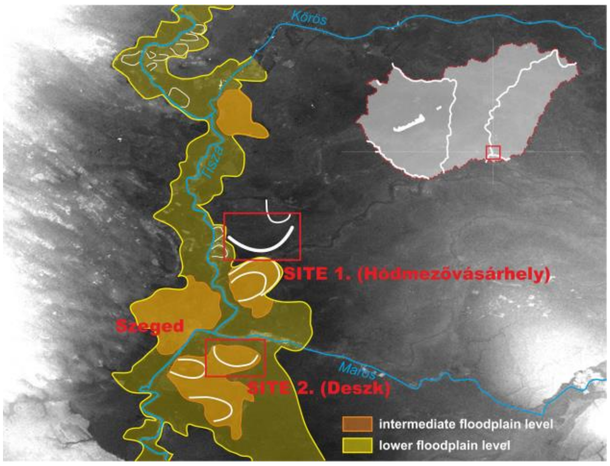

Fig. 1 Location of the studied meanders, the border of the lower and upper floodplain surfaces, and situation of intermediate floodplain levels based on Hernesz (2015)

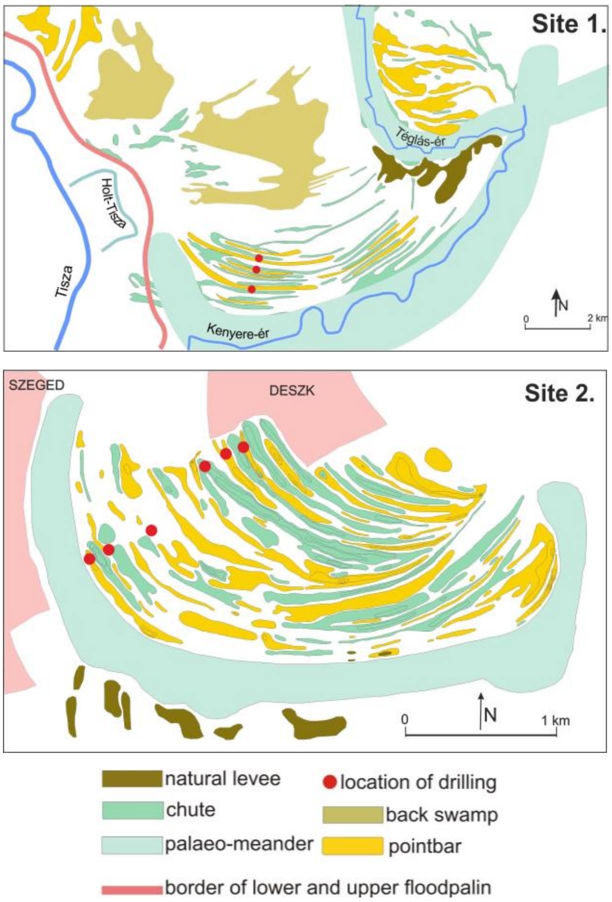

Fig. 2 Geomorphology of the study sites and the location of the drillings

METHODS

The age and development rate of meanders were determined by the means of luminescence dating (OSL). 10 drillings were made to sample pointbar and channel sediments of two megameanders (Fig. 2). Fluvial stratigraphy and sedimentological correlations were set up by laser grainsize analysis (Fritsch Analysette 22 MicroTec plus). OSL samples were taken from layers with increased sand content, using drilling and undisturbed steel cylinders.

In all 12 sediment samples were measured by OSL. Samples were mainly silty, but usually containing an adequate amount of sand for dating, therefore where it was possible the polymineral fine grain and quartz coarse grain fractions were dated simultaneously in order to assess the adequacy of different materials for dating purposes. The preparation of the samples has followed usual laboratory techniques (Aitken, 1998; Mauz et al., 2002). For coarse and fine grain dating the 90-150 μm and the 4-11 μm fractions were used, respectively. The separation of fractions was made by sieving and settling. The carbonate and organic material content was removed by repeated treatment in 10% HCl and 10% H_2O_2. In case of coarse grains, a Na-polytungstanate (LST Fastfloat) heavy liquid separation was applied for the separation of the quartz fraction. This step was followed by a 50 min etching in 40% HF, aiming at removing any remaining feldspar contaminations and the outer layer of quartz for dosimetry reasons. Coarse grains were adhered to stainless steel discs by silicone spray (2 mm mask), fine grains (2 mg/aliquot) were settled to aluminium discs by using acetone. A number of aliquots were prepared for luminescence tests and for equivalent dose (D_e) determination.

Measurements were made using a RISOE DA-15 TL/OSL luminescence reader by applying the SAR (Wintle and Murray, 2006) and DSAR (Roberts and Wintle, 2001) protocols on the coarse grain sand and the fine grain silt fraction, respectively. In terms of fluvial samples usually the sand sized quartz fraction is investigated, assuming that it usually has more chance for complete bleaching during sediment transport. In this case comparative measurements were made to test the applicability of the fine grain component too.

Concerning the coarse grain fraction a combined preheat-cutheat test was used for determining optimal heating parameters during the SAR measurements. Preheat temperatures varied between 200 ºC and 260 ºC, while cutheat temperatures between 140 ºC and 220 ºC. In case of fine grain samples a simple preheat test was applied, with a constant cutheat at 160 °C. During the tests SAR recycling ratios (ratio of two sensitivity corrected luminescence signals generated by identical regeneration doses) and recuperation (thermal and photo transfer of electrons to OSL traps) values were monitored to determine the best thermal treatment. Subsequently, known doses were administered to 5-5 aliquots of each sample and a SAR measurement was run in order to determine the given dose/measured dose ratio (dose recovery test), which is a robust test for assessing the applicability of the SAR procedure. Known doses were set to be close to the preliminary D_e, assessed prior to any of the tests.

SAR measurements were performed on 24-48 aliquots, standard rejection criteria were used to select those aliquots performing well during the measurements (recycling ratio being within 1.00 ± 0.05, D_e error being lower than 10%, recuperation being lower than 5%). Single aliquot D_e values were analysed using the central age and the minimum age models (Galbraiht, 1999) in case of coarse grain and fine grain samples, respectively.

Environmental dose rate (D*) was determined by using high-resolution, extended range gamma spectrometry (Canberra XtRa Coaxial Ge detector), using 500 cm^3 marinelli beakers. Dry dose rates were calculated using the conversion factors of Adamiec and Aitken (1998). Wet dose rates were assessed on the basis of in situ water contents. The rate of cosmic radiation was determined on the basis of burial depth following the method of Prescott and Hutton (1994).

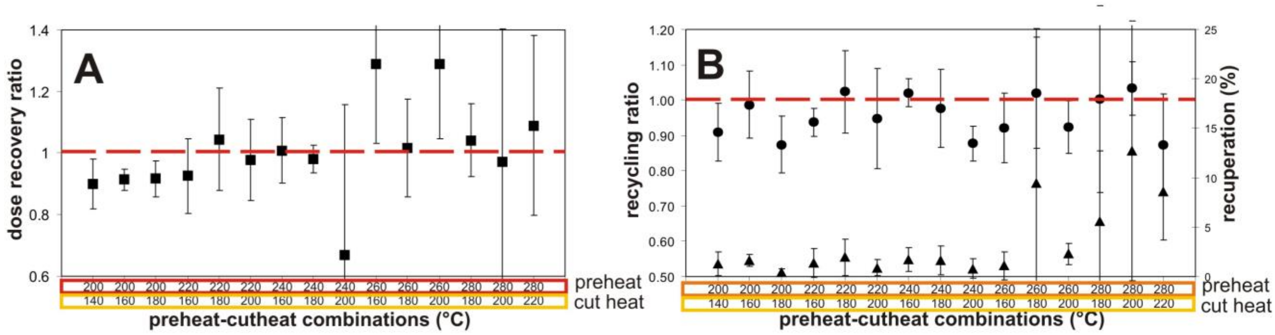

Fig. 3 Results of a combined preheat-cutheat and dose recovery test of a coarse grain quartz sample (OSZ245). A) dose recovery ratio; B) recycling ratio and recuperation

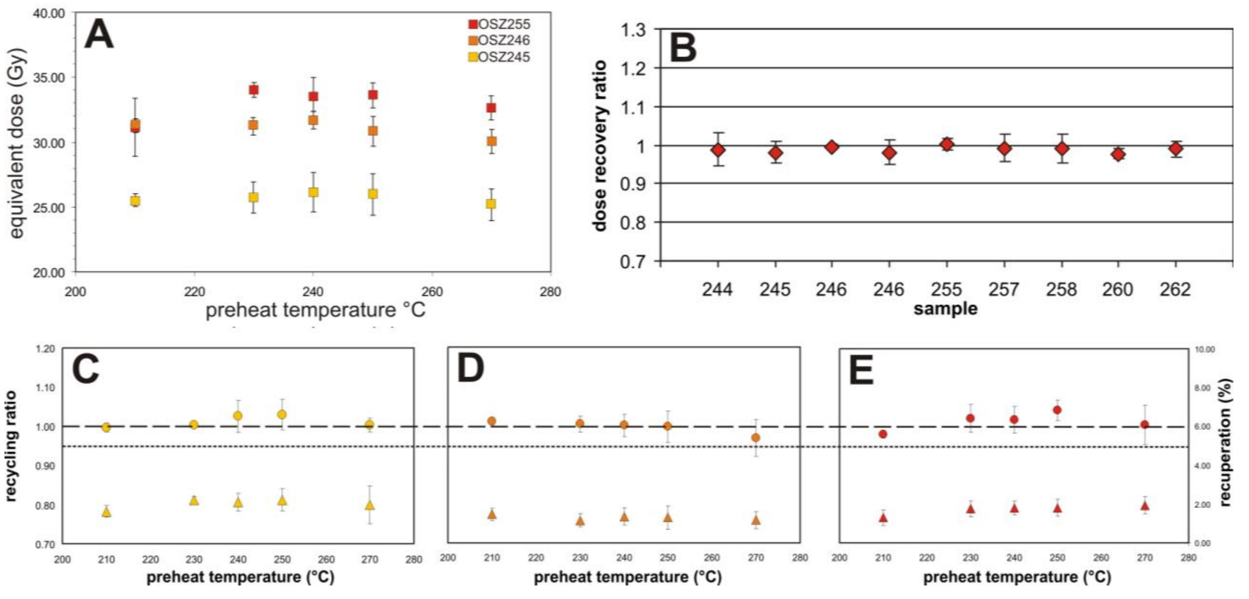

Fig. 4 Preheat and dose recovery test of polymineral fine grain samples. A) D_e at various preheat temperatures, B) The dose recovery ratio values of several fine grain samples, C, D, E) Recycling ratio and recuperation of samples indicated on Fig. 4A, colours are identical

RESULTS AND DISCUSSION

Looking at the thermal tests in general, as it was expected, coarse grain samples showed a much higher scatter in terms of SAR internal check parameters and also in terms of dose recovery ratios than fine grain samples (Fig. 3 and Fig. 4). Concerning recuperation coarse grain samples performed fairly well up till a preheat temperature of 260-280°C (Fig. 3), thus this parameter has not seemed to be problematic in terms of final measurements. However, recycling ratios were rather poor at almost each preheat-cutheat combinations. Acceptable results were received at either the 240°C/160°C (Fig. 3) and the 220°C/160°C combinations. At these temperature settings dose recovery was also within thresholds (Fig. 3).

Meanwhile, in case of fine grain samples a high stability of equivalent doses was observed at various preheat temperatures, and the recovery of artificial doses was also very precise (Fig. 4). Recycling ratios remained close to unity and recuperation was also insignificant (Fig. 4).

As a consequence of the above during the final SAR measurements, aiming at determining D_e, 40-50 % of aliquots had to be rejected in terms of coarse grain quartz samples during the age analysis. However, by applying even stricter rejection criteria for fine grain samples 95 % of results were still applicable.

Following age calculation fine grain results were relatively close to coarse grain result (Table 1, Fig. 5). Significant overestimation was experienced in three cases, on the other hand three other fine grain ages were practically identical to their coarse grain equivalent (Fig. 5). The mean overestimation related to fine grain ages was 1.5 ka, meaning that general trends might be inferred from fine grain fluvial data in the region, and major channel generations can be separated, but the date of shifts and changes can hardly be determined without the use of coarse grain data.

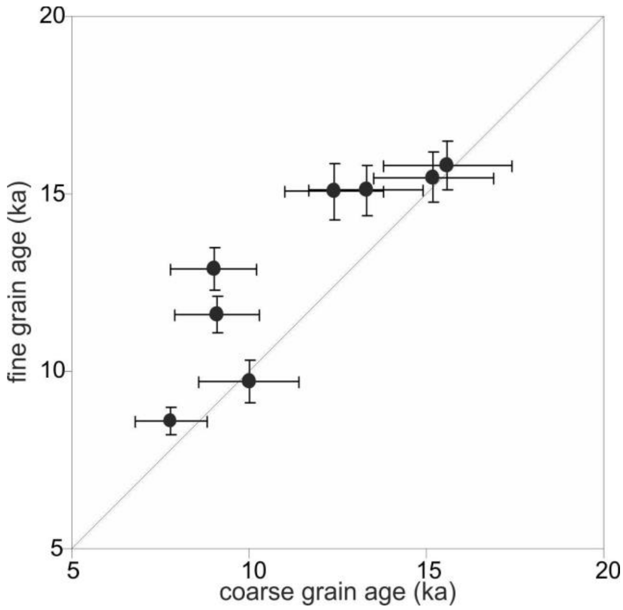

Fig. 5 Coarse grain and fine grain ages plotted against each other in case of samples where both were determined

Based on coarse grain derived ages, the point bars related to the upper floodplain meander (Site 1) started to develop 14-16 ka ago, and were probably formed up till 13-15 ka. Going closer to the palaeochannel, a less elevated bar (drilling C) yielded a coarse grain age of 12.4±1.4 ka at a 2.6 m depth, which is in good correspondence with the topmost sample of drilling B with an age 13.3±1.6 ka (Fig. 6). Consequently, a second phase of channel formation is suggested at this time, which was also accompanied by a slight incision, as the point bar sequence can be separated into two levels (Fig. 6). At a 1.4 m depth however, an age of 7.8±1.0 was received, which is very young compared to previous results and might indicate either post formational aggradation, or a next phase of channel development. Nevertheless, this can only be confirmed if further drillings are made closer to the channel.

Table 1 Dose rate, equivalent dose and age data of the investigated samples

Sample	depth (m)	U (ppm)	Th (ppm)	K (%)	$D^*_{(90\text{-}150\ \mu m)}$ (Gy/ka)	$D^*_{(4\text{-}11\ \mu m)}$ (Gy/ka)	$D_{e\ (90\text{-}150\ \mu m)}$ (Gy)	$D_{e\ (4\text{-}11\ \mu m)}$ (Gy)	Age $_{(90\text{-}150\ \mu m)}$ (ka)	Age $_{(4\text{-}11\ \mu m)}$ (ka)
Site 1										
OSZ255	1.4	2.53±0.24	9.28±1.04	1.73±0.17	2.72±0.14	3.21±0.14	21.14±2.53	27.73±0.30	7.8±1.0	8.6±0.4
OSZ257	2.6	2.60±0.21	9.42±1.05	1.85±0.09	2.64±0.10	3.11±0.13	32.70±3.37	46.9±0.78	12.4±1.4	15.1±0.7
OSZ258	1.1	2.43±0.20	8.85±1.00	1.62±0.08	2.68±0.11	3.18±0.14	39.03±4.39	41.99±0.69	14.5±1.8	13.2±0.6
OSZ260	2.6	2.27±0.15	8.20±0.82	1.54±0.07	2.37±0.09	2.80±0.12	36.96±4.09	44.25±0.57	15.6±1.8	15.8±0.7
OSZ262	2.1	2.82±0.23	10.65±1.17	1.90±0.09	2.93±0.11	3.48±0.14	44.59±4.64	53.74±0.79	15.2±1.7	15.5±0.7
Site 2										
OSZ242	1.4	2.55±0.20	9.44±1.04	1.59±0.08	-	3.43±0.16	-	37.91±0.67	-	11.1±0.5
OSZ244	1.6	2.47±0.17	8.33±0.86	1.42±0.07	-	3.12±0.15	-	42.14±0.62	-	13.5±0.7
OSZ245	1.0	1.74±0.15	6.28±0.74	1.11±0.06	1.99±0.10	2.35±0.13	19.8±2.56	22.74±0.57	10.0±1.4	9.7±0.6
OSZ246	1.3	1.74±0.15	6.28±0.74	1.11±0.06	2.00±0.10	2.37±0.13	18.23±2.34	27.46±0.23	9.1±1.3	11.6±0.5
OSZ247	2.0	2.15±0.17	7.86±0.86	1.35±0.06	-	2.74±0.13	-	33.98±1.1	-	12.4±0.7
OSZ248	1.5	2.64±0.21	8.38±0.96	1.48±0.07	-	3.17±0.15	-	32.99±0.43	-	10.4±0.5
OSZ254	2.2	2.43±0.19	8.34±0.94	1.37±0.07	2.34±0.10	2.80±0.13	20.98±2.59	36.15±0.60	9.0±1.2	12.9±0.6

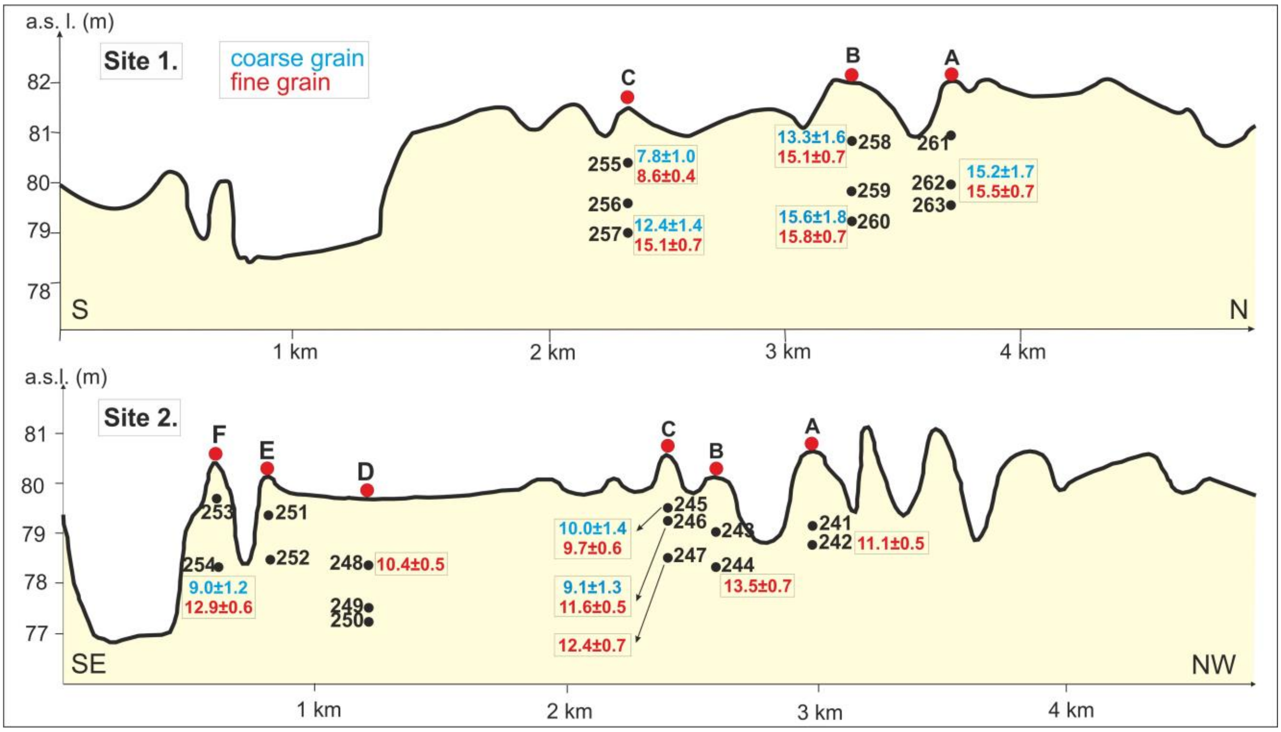

Fig. 6 Coarse and fine grain OSL ages at Site 1 (Hódmezővásárhely) and Site 2 (Deszk)

Concerning Site 2 both coarse grain and fine grain data indicate that the point bar sequence developed relatively intensively between 11 ka and 9 ka, thus one continuous phase of development can be identified. Consequently, lateral development was much faster than in case of the meander on the upper floodplain. Age data indicate that the intermediate floodplain level developed right after the second development stage (at 12-13 ka) of the upper floodplain meander, thus a continuous incision process can be hypothesised during the Pleistoene-Holocene transition.

The difference in the dynamics of meander evolution can partly be explained by changing palaeoenvironment and discharge values. The first phase of evolution on the upper floodplain can be related to a high discharge period during the Bølling-Allerød interstadial as observed at other sites by Gábris and Nádor (2007) and Kiss et al. (2015). Nevertheless, a relatively low intensity of development is inferred, which may refer to the significance of vegetation control under a warm and humid climate. The second phase and the start of the incision process can be related to the Younger Dryas, which obviously brought much lower discharges and although vegetation control was limited also, meander development was slow. This might also be caused by the fact that the major tributary of the Tisza (River Maros) shifted its course frequently in the region at this time (Sümeghy et al., 2013, Kiss et al., 2015). The slight Younger Dryas incision, however, underlies the importance of tectonic forcing over climatic control in the development of floodplain levels along the river.

On the other hand, during the development of the intermediate floodplain level, fluvial processes accelerated suddenly in the Preboreal, as it is resembled by the data of site 2. In this case large discharges as a matter of glacier melting and fairly low vegetation control can explain intense meander formation.

CONCLUSIONS

Based on the tests, both coarse grain and fine grain samples have adequate properties for the application of luminescence dating on fluvial sediments in the Lower Tisza region. Nevertheless, coarse grain samples have poorer characteristics, and therefore extensive measurements are required to have sufficient number of aliquots passing the rejection criteria.

According to the comparative analyses, the resetting of fine grain sediments in the Tisza system is obviously less efficient than that of coarse grains, however overestimation is not general if parallel dated samples of the present study are considered. Therefore, in the given time range, fine grain ages can still provide valuable data for identifying trends, but on their own they are not suitable for drawing sound conclusions. Thus when it is possible some samples has to be subjected to fine grain and coarse grain measurements at the same time to determine the possible degree of overestimation, and this needs to be incorporated to the error term of fine grain results.

Concerning the morphological evolution of the floodplain levels along the river, results support the Late Pleistocene – Early Holocne development of the intermediate floodplain, meaning that the lower floodplain developed in the Holocene, in accordance with previous results (Hernesz, 2015). Incision is suggested to be controlled by tectonics, and therefore it might be possible later to differentiate more stages of the process by the means of further OSL results.

Climate and palaeo-environment on the other hand can have a key role in the dynamics of lateral fluvial development and the rate of point bar formation in case of meanders. Nevertheless, further details can be recovered if detailed measurements are initiated on other mega-meanders of the region.

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