sciendo

Journal of Environmental Geography 14 (1–2), 58–67.

DOI: 10.2478/jengeo-2021-0006
ISSN 2060-467X

THE POTENTIAL USE OF OSL PROPERTIES OF QUARTZ IN INVESTIGATING FLUVIAL PROCESSES ON THE CATCHMENT OF RIVER MUREŞ, ROMANIA

Tamás Bartyik[1], Cristian Floca[2], Elemér Pál-Molnár[1,3], Petru Urdea[2], Diaa Elsayed Hamed[4], György Sipos[1]*

[1]Geomorphological and Geochronological Research Group, Department of Geoinformatics, Physical and Environmental Geography, University of Szeged, Egyetem u. 2-6, 6722 Szeged, Hungary
[2]Department of Geography, West University of Timișoara, B-dul. Vasile. Parvan Nr. 4, 300223, Timișoara, Romania
[3]Department of Mineralogy, Geochemistry and Petrology, University of Szeged, Egyetem u. 2-6, 6722 Szeged, Hungary
[4]National Research Institute of Astronomy and Geophysics, EL Marsad Street 1, Helwan, Cairo 11421, Egypt

*Corresponding author, email: gysipos@geo.u-szeged.hu

Research article, received 15 March 2021, accepted 23 April 2021

Abstract

To understand the functioning of fluvial systems it is important to investigate dynamics of sediment transport and the source of sediments. In case of reconstructing past processes these studies must be accompanied by the numerical dating of sediment samples. In this respect optically stimulated luminescence is a widely used technique, by which the time of sediment deposition can be directly dated. Recently, in various fluvial environments it has been shown that certain luminescence properties of minerals, and especially that of quartz, can be applied as indicators of fluvial erosion and/or sediment provenance. These properties are residual luminescence (or residual dose) and luminescence sensitivity of quartz grains. However, the values of the parameters above are affected by various factors, the importance of which is under debate. The present study therefore aims to assess these factors along a ~560 km long reach of River Mureş (Maros) a relatively large river with a compound surface lithology on its catchment. The research focused on the sandy fraction of modern sediments, collected from the main river and from three tributaries alike. This way not only longitudinal downstream changes, but the influence of tributaries could also be studied. Based on the data, both investigated parameters show a great variation, which can be attributed to the lithological differences of subcatchments and geomorphological drivers, such as erosional activity and potential number of sedimentary cycles, and human activity. However, relationships are not entirely clear and are influenced by the maximum grain size of the samples investigated, and the recycling of previously laid deposits with different properties. Still, when performing detailed dating studies, and tracing sediments from certain parts of the catchment luminescence properties can be a useful tool in the future.

Keywords: sediment tracing, luminescence sensitivity, fluvial sediments, erosion, River Mureş

INTRODUCTION

Alluvial deposits are made up of a complex mixture of mineral grains originating from several subcatchments of a river usually with different lithology and erosional intensity. In sedimentary basins with complex river system, the reconstruction of fluvial processes often requires the tracing of sediments in order to assess major avulsion events, channel migration, or the variable activity of catchments, governed by climatic or tectonic processes (Schumm, 1979). Traditionally, sediment tracing is based on geochemical, mineralogical or other physical, such as magnetic properties by which unique fingerprints are aimed to be identified, which can be then attributed to certain parts of the catchment (e.g. Fryirs and Gore, 2013; Walling, 2013; Collins et al., 2020). However, sediment tracing also requires the numerical dating of sediments, as the comparison of fingerprint properties is only viable if the age of deposition is known (Collins et al., 2020). Not just because temporal changes may occur in the activity of catchments, but because the true proportion of sources can be determined if sediments of the same age are investigated (Walling, 2013).

In this respect, a relatively new method for sediment tracing is the investigation of luminescence properties of sedimentary quartz grains, which can be done parallel to the dating of sediments by the means of optically stimulated luminescence (OSL) (Gray et al., 2019). OSL is based on the fact that certain minerals, such as quartz and feldspars function as natural dosimeters recording total environmental radioactivity in their surroundings since their last exposure to sunlight, i.e. since sediment deposition (Aitken, 1998; Bøtter-Jensen et al., 2003). Subsequent to exposure, incident radioactive particles excite the semiconductor natural crystals and charges reaching the valence band are trapped at crystal defects (e.g. vacancies, interstitial ions). The longer time passes since deposition, the more charges are trapped, and the higher luminescence intensity can be measured in the laboratory when charges are artificially detrapped using light or heat. However, the measured luminescence intensity is depending not only on the age, but also on the charge trapping capacity of the crystals, determined primarily by the number of crystal defects. Consequently, the intensity measured in response to unit radioactive dose is termed as luminescence sensitivity (Preusser et al., 2009; Sawakuchi, 2011; Sharma, 2017; Gray et al., 2019). As luminescence sensitivity is a sample dependent property, thus it has a unique potential in sediment tracing (Gray et al., 2019). This is especially true for quartz, since it can exhibit highly variable sensitivity values, as shown by the study of Bartyik et al. (2021).

Luminescence sensitivity of quartz is primarily determined by the lithology and mineralogy of source rocks. Impurities, developing during the crystallization process, are responsible for the primary charge trapping capacity of the lattice and determine the magnitude of luminescence intensity (Zheng, 2009; Lü and Sun, 2011; Sawakutchi et al., 2011). As pointed out by previous researches, quartz from metamorphic and igneous rocks usually has low sensitivity compared to those originating from sedimentary rocks (Chithambo et al., 2007; Guralnik et al., 2015; Sawakutchi et al., 2018). A difference was also identified based on the formation temperature of rocks (Sawakutchi et al., 2011). Thus, crystallization temperatures can be of significant influence on quartz sensitivity (Sharma, 2017; Sawakutchi et al., 2020).

In the meantime, luminescence sensitivity can increase due to geomorphological processes, most likely as a consequence of recurring sedimentary cycles and long transportation distance, meaning repeated sunlight exposure and natural dosing (Fitzsimmons, 2011; Wintle and Adamiec, 2017). For example, the high luminescence sensitivity of Australian sedimentary quartz is usually explained by the extensive and the repeated reworking of sediments (Pietsch et al., 2008; Fitzsimmons et al., 2010; Fitzsimmons, 2011). Similarly, Preusser et al. (2006) claimed that the low luminescence sensitivity of quartz in sediments of New Zealand is primarily caused by their short sedimentary history. In another study, for Australian river sediments, Gliganic et al. (2017) observed an increase in luminescence sensitivity going downstream. However, no such tendency was detected in terms of the Amazon River Basin (Sawakuchi et al., 2018), where differences and downstream change of quartz sensitivity could rather be related to the lithological background of subcatchments (Sawakuchi et al., 2012). Beside sediment cycling, the mode of sediment transport can also have significant role in determining the natural sensitivity of grains (Li and Wintle, 1991,1992). Though, in her study on Australian quartz from various depositional environments Fitzsimmons (2011) found no systematic sensitivity difference between aeolian and water-lain sediments. The influence of both lithological background and sedimentary prehistory of samples thus proved to be important in the level of luminescence sensitivity.

Beside sensitivity, other OSL properties can also be used to investigate fluvial systems, namely if exposure to sunlight is not of adequate length, residual luminescence signals may be reserved in the crystal lattice (Godfrey-Smith et al., 1988; Tóth et al., 2017; Smedley et al., 2019). This often occurs, since turbulence, together with water depth attenuate the intensity of sunlight reaching the grains and thus lead to reduced bleaching (Gemmell, 1988; Berger, 1990; Rendell et al., 1994). Although residuals can adversely affect the accuracy of the dating procedure and usually lead to age overestimation, they can also be applied to investigate the sedimentary dynamics and erosional capacity of river channels (Fiebig and Preusser, 2007; Sipos et al., 2016; Tóth et al., 2017), as far as high residuals indicate the proximity of the sediment source.

As it has been shown above, the OSL properties of quartz grains can be influenced by many factors, and the understanding of these factors requires the systematic investigation of river systems. From this point of view, River Mureş can be a good choice because sedimentary, igneous and metamorphic rocks are all present on its relatively large drainage basin. Additionally, due to the elongated shape of the catchment the role of subcatchments with different surface lithology can be distinguished relatively well on its upper reaches, while along its lower reaches no major tributaries join the river, primarily geomorphological processes should determine the luminescence properties of quartz grains on this section.

Therefore, the aim of the present research was to investigate the change of some key luminescence properties along an approximately 560 km long section of River Mureş in order to see how subcatchments with different surface lithology, and transportation distance, i.e. repeated reworking of sediments, affect residual doses and luminescence sensitivity of quartz grains. The research also enabled the assessment of the applicability of luminescence properties as a sediment tracer in a relatively large river system.

STUDY AREA AND SAMPLING

River Mureş (Maros) is the fourth largest waterflow in the Carpathian Basin. The area of the its catchment is approx. 30 000 km^2, the majority of which falls in Romania and drains the waters of the Transylvanian Basin (Laczay, 1975). The upstream part of catchment (250x100 km) is rectangular, while the downstream section (200x30 km) starting from Deva is elongated (Urdea et al., 2012). Concerning river morphology and surface lithology, the course of the river can be separated into four major reaches (Fig. 1). The uppermost, steepest upland reach from the source of the river till Deda is dominated by volcanic rocks (Urdea et al., 2012; Pál-Molnár et al., 2015). The next section from Deda to Alba Iulia is characterized by a significantly lower slope as the river enters the hilly landscape of the Transylvanian Basin, built up of Neogene marine and lacustrine sedimentary rocks (Baranyi et al., 2020). The largest tributary of the river, Târnava (Küküllő) is also situated in this lithological domain. However, on the downstream part of this

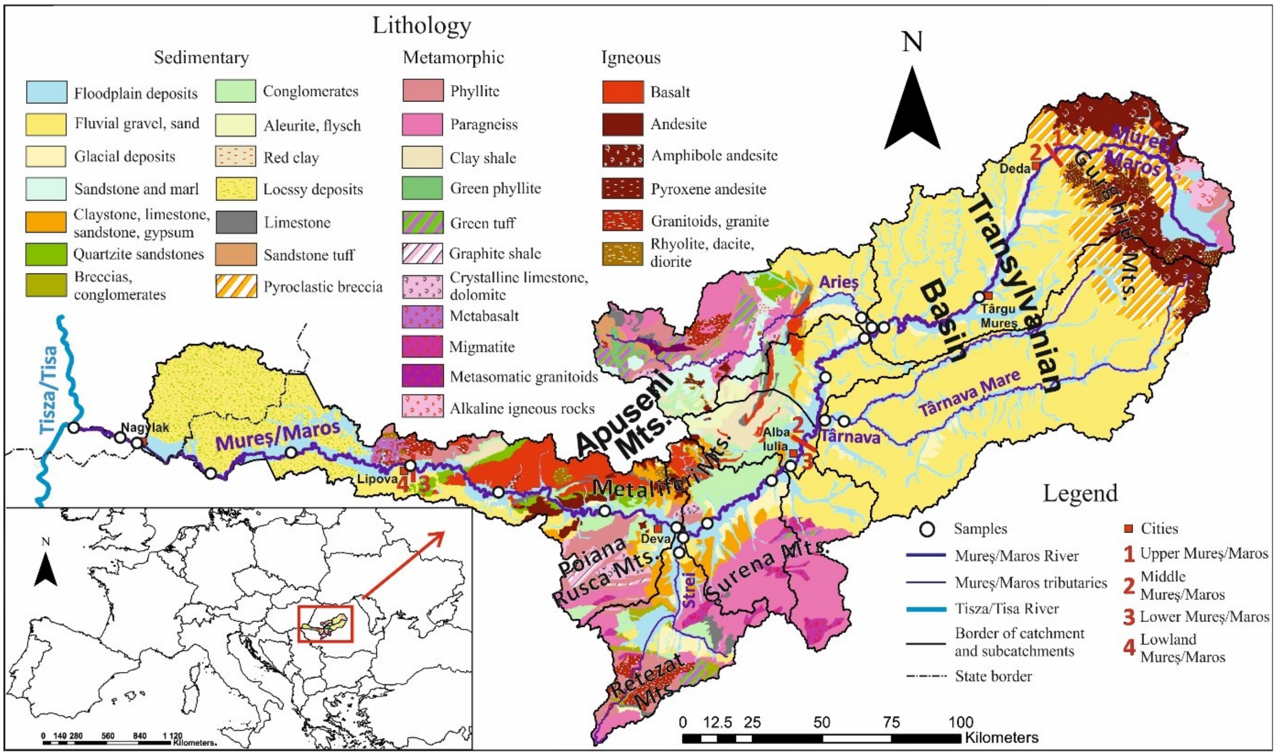

Fig. 1 The surface lithology of the catchment of River Mureş and the location of sampling points (Based on Harta geologică a R. S. România, sc. 1:200.000, 1967 maps).

section tributaries, such as the Arieş (Aranyos), already introduce to the main river sediments produced in the Apuseni Mountains with a complex mixture of surface lithology comprised of metamorphic, magmatic/ plutonic, volcanic and sedimentary rocks of various origin (Kounov and Schmid, 2013; Silye, 2015). Downstream of Alba Iulia, the river flows till Lipova along the tectonic line dividing the Apuseni Mountains and the Southern Carpathians. In this area, small northern tributaries carry the sediments of the Metaliferi (Transylvanian Ore) Mountains, rich in volcanic rocks and ores, to the main river. Larger southern tributaries, such as the Sebeş (Sebes) and Strei (Sztrigy) transport their sediments mostly from the metamorphic and plutonic rocks of the Southern Carpathians (Bojar et al., 2010; Iancu and Seghedi, 2017). On the lowland section, downstream of Lipova the Mureş has built an extensive alluvial fan, on which it has frequently changed its direction even in the Holocene, thus here it reworks its own alluvial deposits (Borsy, 1989; Kiss et al., 2013).

In the present study, a 565 km section between Târgu Mureş and the confluence to the Tisza was studied, along with three of the largest tributaries of the river: Arieş, Târnava, and Strei (Fig. 1).

To investigate the change in luminescence sensitivity, modern sediment samples with similar geomorphological position were collected from the river channel, usually from side bars, point bars or sand sheets on the river bank (Fig. 2A-B). Potential sampling points were pre-selected using satellite images taken at low water periods. Sampling was carried out at 16 locations along the Mureş River, while in the case of tributaries two samples were collected upstream of their confluence at 2-4 rkm and at 8-14 rkm in each case. Thus, we sampled a total of 22 locations in the entire study area (Fig. 1, Table 1). Sampling took place during the autumn low water period. At each point, we aimed to collect samples rich in sand. In the case of the samples on the bank of the channel, sample collection was made using a spatula (Fig. 2C). In case of river bars, sampling was made using a PVC tubes (Fig. 2D).

METHODS

Laboratory processing of the collected samples followed general laboratory techniques (Mauz et al., 2002; Sipos et al., 2016). After removing the light exposed outer layer in the dark laboratory the samples were dried. Then by sieving the 90-150 µm, 150-220 µm and 220-300 µm fractions of samples were separated by wet sieving. In many cases, however, there was enough quartz for the measurements only by mixing the previously separated fractions (Table 1). The carbonate and organic material content of samples were removed by repeated treatment in 10% HCl and 10% H_2O_2. The quartz fraction was separated by using LST (sodium polylungstanate) heavy liquid. This step was followed by a 50 min 40% HF etching to remove unwanted feldspar residues as well as the external shell of quartz grains. For measuring residual doses purified quartz samples were adhered on Ø10 mm stainless steel discs using silicone spray and a 2 mm mask. For sensitivity measurements, Ø10 mm diameter stainless steel cups were used, into which a 6 mg of sample was measured with an analytical balance.

Fig. 2 Typical sample collection sites include point bars (A) and side bars (B). Sampling was performed from the uppermost, thus freshly deposited sediments by spatula (C) or plastic tube (D) for undisturbed samples.

Both residual dose and luminescence sensitivity measurements were performed using a RISØ TL-DA-20 luminescence reader. A $^{90}Sr/^{90}Y$ βsource was used for irradiation, while an EMI ET9107 photomultiplier (PMT) with a Hoya U-340 filter was used for detecting the luminescence signal. The residual dose, i.e. the equivalent dose of modern samples was determined using the single aliquot regeneration (SAR) protocol (Wintle and Murray, 2006).

Sensitivity measurements were performed based on the procedures detailed in Bartyik et al. (2021). First, 5 aliquots from each sample were bleached by using blue LEDs to remove the natural signal. Then each aliquot received a uniform β-dose of 22 Gy. The luminescence response elicited by this dose was measured using the Continuous Wave OSL (CW-OSL) technique during which the LED power was always the same. Background was subtracted using the last 5 s of the decay curve. Results were then normalized by the mass of the samples, measured by an analytical scale. This normalized intensity was considered as the "normalized CW-OSL sensitivity" of the samples.

To examine the lithological background and to delineate the main surface lithological units, 1: 200 000 scale geological maps were used (Harta geologică a R. S. România, 1967). The catchment of the Mureş is covered by 15 map sheets, which were georeferenced using ESRI ArcMap. After georeferencing the map sheets, surface lithology was digitized. The proportion of different rock types was determined for the investigated subcatchments and compared to the luminescence sensitivity values obtained.

RESULTS AND DISCUSSION

Residual dose

Based on the SAR measurements, each sample had a low level of natural luminescence, meaning that grains were well bleached (Fig. 3A-B). In case of one sample (Sample 565 rkm) no curve could be fitted to the plot of laboratory doses and luminescence responses (dose response curve) (Fig. 3C-D). In case of the other samples fitting was successful, and obtained residual doses varied between 0.4 and 3.9 Gy, however results had a high standard error (Table 1). Thus, coarse grain paleo fluvial samples subjected to dating in the area can overestimate the true age of deposition by around 0.2-2.0 ka if a usual 2 Gy/ka dose rate is taken (Kiss et al., 2014; Tóth et al., 2017).

Comparing these results with the residual values measured nearly 417 km long Hungarian section of the Danube by Tóth et al. (2017), it can be seen that much higher values can be observed in the case of River Mureş. In his research the mean residual dose of coarse grain quartz was 0.1±0.01 Gy while the maximum value was only 0.56±0.17Gy, which cause a negligible overestimation between 60 and 120 y in the area. On the other hand, an overestimation of 1.2 -2.3 ka has already been found for the fine grain samples, which is similar to the Mureş coarse grain quartz values. Regarding that Danube, however, Fiebig and Preusser (2007) measured very high residual dose (around 6.1 Gy) in their research on the Vienna section, which were explained by anthropogenic effects.

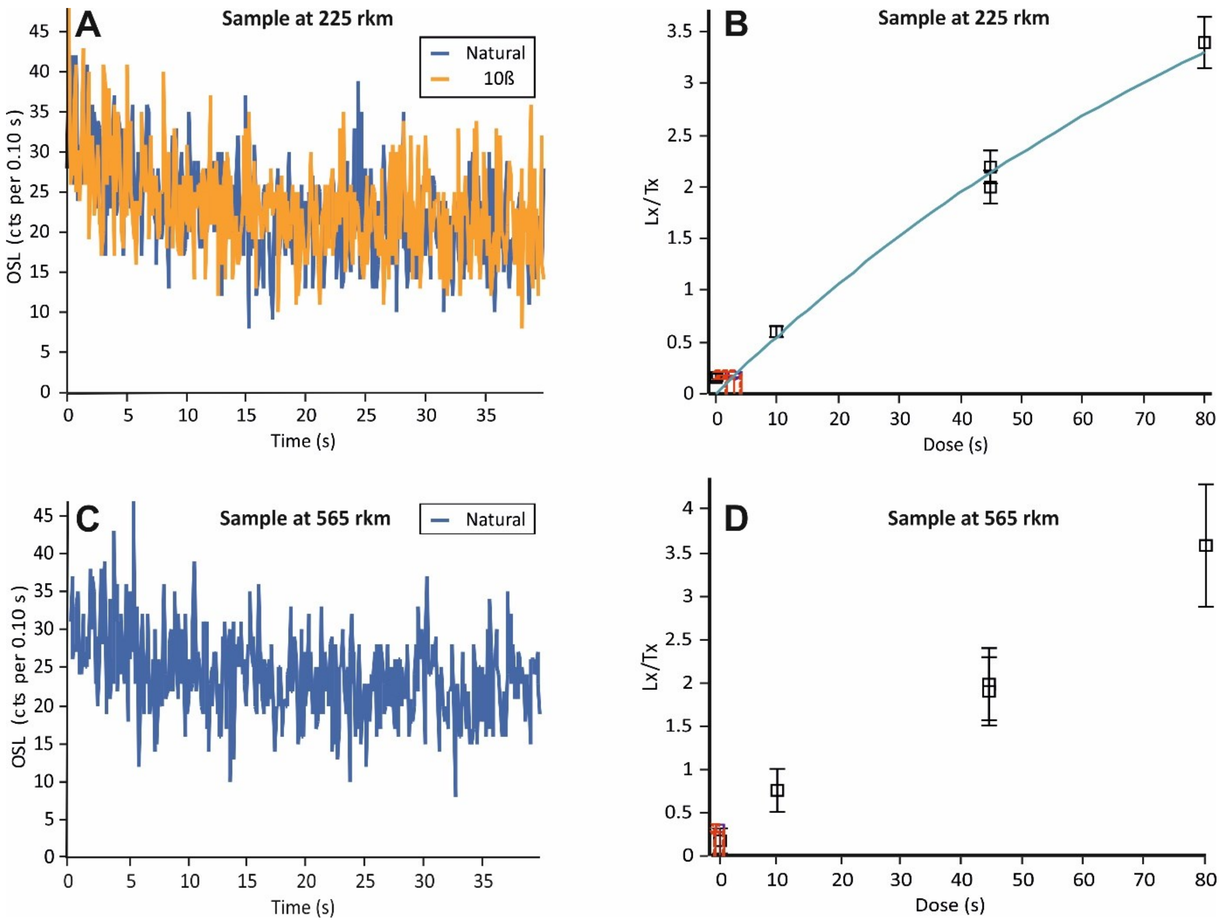

Fig. 3 Dose response curves of two samples. Sample 225 rkm sample (A, B) showed a typical decay with a low signal, while at 565 rkm (C, D) it can be seen that due to a signal close to 0 s, a line cannot be fitted to the data.

If residual doses are analyzed along the longitudinal profile of the river (Fig. 4 and Table 1) it is obvious that in general, there is a decreasing trend in residual dose values. It is in accordance with the fact that channel sediments should be reworked more times towards downstream, and therefore bleaching by sunlight can be more complete. However, local peaks can be observed, and tributaries also show different values. Upstream of the conjunction of River Arieș (Aranyos) the value of the measured residual dose is 2.07±0.60 Gy (Sample 491 rkm), and although the quartz grains of Arieș sediments have a highly variable residual dose they stay in the same range and seemingly do not affect significantly the values measured downstream of the confluence. The first and largest peak can be seen in case of Sample 448 rkm with a value of 3.88±0.79 Gy.

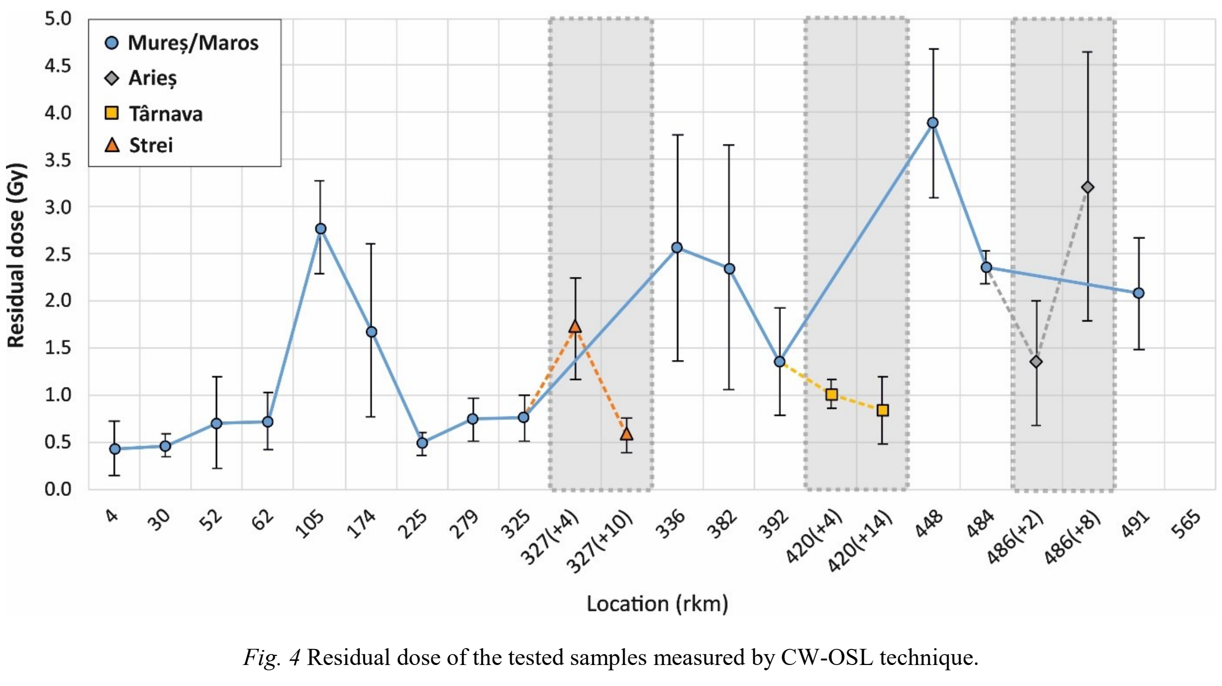

Fig. 4 Residual dose of the tested samples measured by CW-OSL technique.

The sampling site is located on reach where only very short tributaries, mostly arriving from the Apuseni Mountains, join the river, therefore the sediments cannot be resetted completely before reaching the Mureş (Fig. 1 and 4).

Compared to River Arieş the sediments of the Târnava (Küküllő) are bleached more completely and have a more uniform value (Fig. 4). It is possibly related to the fact that the longest tributary of the Mureş has a fairly low gradient, therefore channel sediments can go through several cycles of bleaching before arriving to the confluence zone. Seemingly, the mixing of low residual dose Târnava quartz grains reduces the residual dose level in the sediments of the main river as well, however, that the next sampling point (Sample 392 rkm) is 30 km downstream of the confluence (Fig. 4).

The second, moderate peak in residual dose values (2.56±1.20 Gy and 2.35±1.3 Gy at 382 and 336, rkm, respectively) can be observed downstream of the confluence of River Sebeş (Sebes) on a section where the Mureş is laterally eroding Cretaceous conglomerates and sandstones at the foothills of the Metaliferi Mountains (Fig. 1 and 4). Besides, on this section high gradient and short tributaries join the river, which can also explain the presence of less bleached grains in the sediment mixture. A similar phenomenon was identified by Tóth et al. (2017) along the Danube, where the erosion of loess bluffs resulted an order of magnitude increase in quartz residual doses. On the next 10 km (between 336 and 325 rkm) residual dose values drop by 60-70 %, which can hardly be explained solely by the natural bleaching of grains in the channel, but rather by the entering of River Strei (Sztrigy), which introduces low residual dose sediments to the main river (Fig. 4).

Low values persist till the Lipova Gate, where River Mureş enters the lowlands. Here a third peak of residuals appears, which might be explained either by extensive in-channel gravel mining, mostly on the Lipova section and downstream, and/or the natural erosion of Pleistocene deposits. Nevertheless, by reaching the distal part of the alluvial fan, residual doses decrease to their lowest values along the entire investigated reach (Fig. 4).

Luminescence sensitivity

The downstream change of luminescence sensitivity, that can be affected either by surface lithology or transportation distance show a similar pattern to that of residual dose values on the upstream reaches of River Mureş (Fig. 4 and 5). The first two quartz samples (Sample 565 rkm and 491 rkm) have practically an identical luminescence sensitivity (154±19 and 159±19 cts/mg/Gy). These values fit well to the mean luminescence sensitivity value of five Pleistocene age sediment samples (167±9 cts/mg/Gy) collected from various points on the alluvial fan of the river and investigated by Bartyik et al. (2021). Based on this, it could be expected that there is no significant variation in CW-OSL sensitivity values along the river.

Table 1 Summary of the measured data of quartz extracts. (In case of tributaries the location refers to the distance from the confluence with the Mureş.)

River	Location of sampling points (rkm)	Grain size (μm)	Residualdose (Gy)	Normalized CW-OSL sensitivity (cts/mg/Gy)
Mureş	4	90-300	0.44±0.29	124±22
	30	90-300	0.47±0.13	69±16
	52	90-300	0.71±0.48	37±5
	62	150-220	0.72±0.31	202±60
	105	150-220	2.78±0.49	179±47
	174	90-300	1.69±9.89	71±10
	225	90-150	0.48±0.12	322±34
	279	90-150	0.74±0.23	225±26
	325	90-150	0.74±.023	232±24
	336	90-150	2.56±1.20	132±7
	382	90-220	2.35±1.3	139±27
	392	150-220	1.35±0.57	124±7
	448	90-150	3.88±0.79	587±167
	484	90-220	2.36±0.18	305±72
	491	90-150	2.07±0.6	158±19
	565	90-150	no data	154±19
Arieș	486+2	90-150	1.34±0.66	204±13
	486+8	90-220	3.21±1.43	294±36
Târnava	420+4	90-220	1.01±0.16	146±22
	420+14	90-220	0.84±0.36	173±35
Strei	327+4	90-150	1.71±0.54	179±15
	327+10	150-220	0.57±0.18	118±18

However, values increase considerably going downstream, supposedly by the joining of River Arieş (Fig. 5), since the luminescence sensitivities of Arieş quartz samples are 204±13 cts/mg/Gy and 294±36 cts/mg/Gy and a very similar value is obtained just below the confluence as well (Fig. 5). This way, in the confluence zone the Arieş values almost double the level of quartz luminescence sensitivity. Moreover, at the next sampling site (448 rkm) the sensitivity reaches its maximum on the entire studied reach (Table 1). If surface lithology is considered, the upper catchment of the Mureş is dominated by erodible Neogene sedimentary rocks, and seemingly the quartz fraction of these has a moderate CW-OSL sensitivity. Although, the lower reaches of the Arieş flow across the same Neogene units, its headwaters are in the Apuseni Mountains and its catchment can be characterized by a complex lithology, comprised mostly of various igneous and metamorphic rocks, such as paragneiss, phillite, basalt and metasomatic granitoids (Fig. 1). Although, usually quartz originating from igneous and

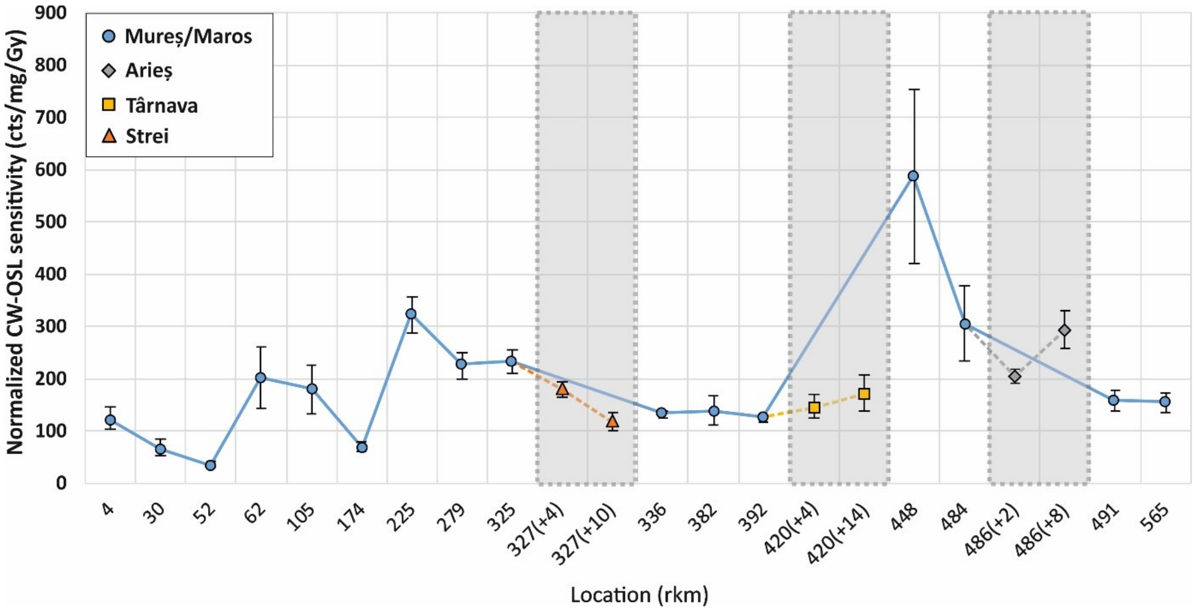

Fig. 5 Normalized CW-OSL sensitivity values of the tested samples.

metamorphic rocks has a relatively low luminescence sensitivity (Chithambo et al., 2007; Guralnik et al., 2015; Sawakutchi et al., 2018), on the other hand Sawakutchi et al. (2011) emphasized that high crystallization temperatures can its value increase. Considering these facts, granitoids affected by metasomatosis, and/or paragneisses metamorphosed from sedimentary rocks can be responsible for the experienced increase in luminescence sensitivity. However, the confirmation of this hypothesis needs further sampling in the area.

Nevertheless, it is also clear from the high standard error of these samples (Fig. 5, Table 1) that high sensitivity of quartz grains originated from the Arieș has limited effect on the overall values of Mureș sediments. This can be the reason for the observation that by the entering of Târnava CW-OSL sensitivity decreases to its original level. The catchment of this tributary is built up by the same Neogene sedimentary rocks as that of the Mureș, consequently, measured sensitivity values (146±22 and 173±35 cts/mg/Gy) are very similar (Fig. 5).

The high erosive capacity of the river, shown by the increase of residual doses downstream of the Târnava is not affecting sensitivity values, thus the quartz of Cretaceous conglomerates supposedly has a similar luminescence sensitivity as that of the Neogene sedimentary rocks. However, three samples (Sample 325, 279 and 225 rkm) collected downstream of the confluence of River Strei show an increasing trend again. Based on the luminescence sensitivity of quartz grains extracted from Strei sediments, this increase cannot be attributed unambiguously to the Strei itself (Fig. 5, Table 1). On the 100 km-long reach represented by the three samples no significant tributaries join the river, and residual doses showed a decreasing trend (Fig. 4). It refers to repeated bleaching of quartz grains. In these circumstances it is appealing to claim that sensitivity increase is due to geomorphological reasons. On the other hand, the jump in sensitivity just 2 rkm downstream of the Strei confluence and the lithological complexity found on both banks of River Mureş points to the possible role of geological reasons. Nevertheless, surface lithology on this section is mostly dominated by volcanic rocks such as andesite and basalt, renown of containing low sensitivity quartz in general (Sawakutchi et al., 2018), and as the most downstream sample of this section (Sample 225 rkm) has the lowest residual dose and the highest CW-OSL sensitivity (322±34 cts/mg/Gy) from all, the significance of geomorphic factors seems also inevitable.

In this sense, the remarkable drop in case of Sample 174 rkm (70±10 cts/mg/Gy) might refer to the mixing of external sediments, possibly as a consequence of in-channel quarrying and related erosion, as it was suggested on the basis of residual dose increase earlier (Fig. 4). It has to be noted also that this sample contained larger quartz grains than any other samples before (Table 1), and by the increased degree of self-absorption during OSL stimulation this may also contribute to reduced sensitivity values.

In case of the following samples (Sample 105 and 62 rkm) values tend to grow again (179±47 and 202±60 cts/mg/Gy), though with a high standard error, referring again to a nonuniform sensitivity of quartz grains. Since, on the basis of residual doses the mixing of palaeo-sediments is suggested on this section, sensitivity increase might be attributed to these. This draws the attention to the potential temporal change in the luminescence sensitivity of channel sediments. It can be explained either by the differential activity of subcatchments under glacial and interglacial climate regimes, or the dynamics of fluvial activity, i.e. the number of sedimentary cycles through which grains arrive to the alluvial fan.

To complicate the picture above, luminescence sensitivity values at the edge of the alluvial fan drop again (Sample 52 rkm) and reach their minimum

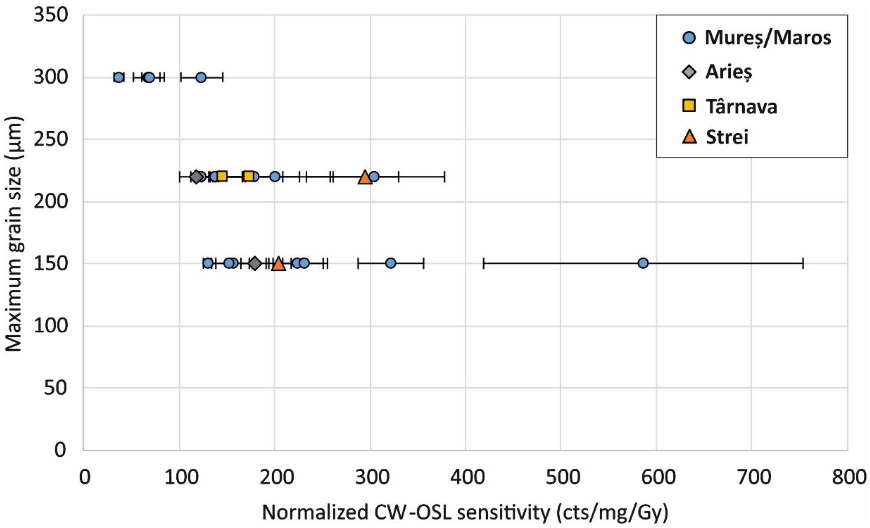

Fig. 6 CW-OSL sensitivity plotted against the maximum grain size of the investigated samples.

(37±5 cts/mg/Gy) on the entire studied section (Fig. 5, Table 1). Just like in the case of Sample 174 rkm, this and the following two samples are composed of larger quartz grains. Consequently, it seems that if maximum grain size of the investigated fraction is above 220 µm then measured values considerably decrease (Fig. 6). However, if fractions between 90-150 µm or 150-220 µm are compared then no such tendency can be identified. The analysis of this parameter needs further measurements on different fractions of the same sample.

CONCLUSIONS

The combined analysis of quartz OSL residual doses, luminescence sensitivity, surface lithology, grain size and transportation distance in terms of modern samples allowed to assess what factors may affect luminescence parameters at most, and if these can be applied late for sediment sourcing and the reconstruction of fluvial processes. In terms of both luminescence parameters it was clearly proven that subcatchment and river reach scale factors can highly influence the downstream variation of luminescence parameters.

Concerning OSL residual doses, in accordance with the general model, by the increase of transportation distance values show a decreasing tendency as a consequence of repeated bleaching. Based on the results, local and reach scale increase in values can be related to either 1) short tributaries carrying sediments undergone limited sedimentary cycles; 2) increased erosion of palaeo-sediments and sedimentary rocks by the main river; or 3) in-channel quarrying. All these processes introduce grains with a high palaeo-dose to the sediment mixture of the main river, which then increases the value of the measured residual dose.

Although, the length of the investigated river reach (565 km) was considerable, no clear downstream increase in luminescence sensitivity was observed as opposed to some previous research (Pietsch et al., 2008; Fitzsimmons, 2011). According to the data of the present study, sensitivity values showed local and reach scale increase in relation with 1) the inlet of Arieş sediments, partly produced from granitoids and paragneiss as opposed to the sediments of the Upper Mureş originating mostly from Neogene sedimentary rocks; 2) repeated sedimentary cycles on reaches where no significant tributaries join the river. Differences in surface lithology, therefore, do affect OSL sensitivity, but this can be used for sediment sourcing only in case of one out of the three investigated tributaries. Meanwhile, the role of transportation distance and sediment recycling cannot be unambiguously confirmed. A major reason for this, is that other parameters, such as the maximum grain size and related self-absorption of investigated quartz extracts can also affect the results. Moreover, especially on the lowland section of River Mureş unexpected drops in values were experienced, drawing attention to the significance of temporal differences in sediment dynamics and its potential effect on quartz luminescence sensitivity. Consequently, reliable sediment sourcing by the means of OSL sensitivity requires further investigations in the study area. However, as shown by the results, the combination of different luminescence properties can help in the assessment of both present and past fluvial processes.

ACKNOWLEDGMENTS

This work was supported by the Hungarian National Research, Development and Innovation Office [grant number: K119309 and K135793].

References

Aitken M. J. 1998. An Introduction to Optical Dating. Oxford University Press. London.

Baranyi V., Bakrač K., Krizmanić K., Botka D., Tóth E., Magyar I. 2021. Paleoenvironmental changes and vegetation of the Transylvanian Basin in the early stages of Lake Pannon (late Miocene, Tortonian). *Review of Palaeobotany and Palynology* 284, 104340. DOI: 10.1016/j.revpalbo.2020.104340

Bartyik T., Magyar G., Filyó D., Tóth O., Blanka-Végi V., Kiss T., Markovic S., Persoiu I., Gavrilov M., Mezősi G., Sipos Gy. 2021. Spatial differences in the luminescence sensitivity of quartz extracted from Carpathian Basin fluvial sediments. *Quaternary Geochronology* 64, 101166. DOI: 10.1016/j.quageo.2021.101166

Berger G. W. 1990. Effectiveness of natural zeroing of the thermoluminescence in sediments. *Journal of Geophysical Research* 95 (B8), 12375–12397. DOI: 10.1029/JB095iB08p12375

Bojar A.-V., Bojar H.-P., Ottner F., Grigorescu D. 2010. Heavy mineral distributions of Maastrichtian deposits from the Haţeg basin, South Carpathians: Tectonic and palaeogeographic implications. *Palaeogeography, Palaeoclimatology, Palaeoecology* 293 (3-4), 319–328. DOI: 10.1016/j.palaeo.2009.10.002

Borsy Z. 1989. Az Alföld hordalékkúpjainak negyedidőszaki fejlődéstörténete (The Quaternary development of the Great Hungarain Plain). *Földrajzi Értesítő* 38 (3-4), 211–224. (in Hungarian)

Bøtter-Jensen L., McKeever S. W. S., Wintle A. G. 2003. Optically Stimulated Luminescence Dosimetry. Elsevier Science, The Netherlands. ISBN: 0-444-50684-5

Chithambo M. L., Preusser F., Ramseyer K., Ogundare F.O. 2007. Time-resolved luminescence of low sensitivity quartz from crystalline rocks. *Radiation Measurements* 42 (2), 205–212. DOI: 10.1016/j.radmeas.2006.07.005

Collins A. L., Blackwell M., Boeckx P. et al. 2020. Sediment source fingerprinting: benchmarking recent outputs, remaining challenges and emerging themes. *Journal of Soils Sediments* 20, 4160–4193. DOI: 10.1007/s11368-020-02755-4

Fiebig M., Preusser F. 2007. Investigating the amount of zeroing in modern sediments of River Danube, Austria. *Quaternary Geochronology* 2 (1), 143–149. DOI: 10.1016/j.quageo.2006.09.001

Fitzsimmons E., Edward J. R., Timothy T. B. 2010. OSL dating of southeast Australian quartz: A preliminary assessment of luminescence characteristics and behaviour. *Quaternary Geochronology* 5 (2-3), 91–95. DOI: 10.1016/j.quageo.2009.02.009

Fitzsimmons E. 2011. An assessment of the luminescence sensitivity of Australian quartz with respect to sediment history. *Geochronometria* 38 (3), 199–208. DOI: 10.2478/s13386-011-0030-9

Fryirs K., Gore D. 2013. Sediment tracing in the upper Hunter catchment using elemental and mineralogical compositions: Implications for catchment-scale suspended sediment (dis)connectivity and management. *Geomorphology* 193, 112–121. DOI: 10.1016/j.geomorph.2013.04.010

Gemmell A. M. D. 1988. Zeroing of the TL signal in sediment undergoing fluvioglacial transport. An example from Austerdalen, Western Norway. *Quaternary Science Reviews* 7(3-4), 339–345. DOI: 10.1016/0277-3791(88)90026-1

Gliganic L. A., Cohen T. J., Meyer M., Molenaar A. 2017. Variations in luminescence properties of quartz and feldspar from modern fluvial sediments in three rivers. *Quaternary Geochronology* 41, 70–82. DOI: 10.1016/j.quageo.2017.06.005

Godfrey-Smith D. I., Huntley D. J., Chen W. H. 1988. Optical dating studies of quartz and feldspar sediment extracts. *Quaternary Science Review* 7 (3-4), 373–380. DOI: 10.1016/0277-3791(88)90032-7

Gray H. J., Jain M., Sawakuchi A. O., Mahan S. A., Tucker G. E. 2019. Luminescence as a sediment tracer and provenance tool. *Reviews of Geophysics* 57 (3), 987–1017. DOI: 10.1029/2019RG000646

Guralnik B., Ankjærgaard J. M., Murray A. S., Müller A., Wälle M., Lowick S. E., Preusser F., Rhodes E. J., Wu T.-S., Herman F. 2015. OSL-thermochronometry using bedrock quartz: a note of caution. *Quaternary Geochronology* 25, 37–48. DOI: 10.1016/j.quageo.2014.09.001

Harta geologică a R. S. România 1967. sc. 1:200.000, Institutul Geologic, Bucureşti.

Iancu V., Seghedi A. 2017. The South Carpathians: Tectono-Metamorphic Units related to Variscan and Pan-African inheritance. *Geo-Eco-Marina* 23, 245–262. DOI: 10.5281/zenodo.1197110

Kiss T., Sümeghy B., Hernesz P., Sipos Gy., Mezősi G. 2013. Az Alsó-Tisza menti ártér és a Maros hordalékkúp késő-pleisztocén és holocén fejlődéstörténete. (Late Pleistocene and Holocene development of the Lower Tisza floodplain and the alluvial fan of the River Maros). *Földrajzi Közlemények* 137, 269–277. (in Hungarian)

Kiss T., Sümeghy B., Sipos Gy. 2014. Late Quaternary paleodrainage reconstruction of the Maros River alluvial fan. *Geomorphology* 204, 49–60. DOI 10.1016/j.geomorph.2013.07.028

Kounov A., Schmid M. S. 2013. Fission-track constraints on the thermal and tectonic evolution of the Apuseni Mountains (Romania). *International Journal of Earth Sciences* 102, 207–233. DOI: 10.1007/s00531-012-0800-5

Laczay I. 1975. A Maros vízgyűjtője és vízrendszere (The catchment area and water system of the Mures). In: Csoma, J., Laczay, I. (ed.). Vízrajzi Atlasz Sorozat 19. kötet. Maros 1. fejezet. *Hidrográfia, geomorfológia.* Budapest, 4–6. (in Hungarian)

Li S. H., Wintle A. G. 1991. Sensitivity changes of luminescence signals from colluvial sediments after different bleaching procedures. *Ancient TL* 9, 50–54.

Li S. H., Wintle A. G. 1992. Luminescence sensitivity change due to bleaching of sediments. *Nuclear Tracks and Radiation Measurements* 20 (4), 567–573. DOI: 10.1016/1359-0189(92)90006-H

Lü T., Sun J. 2011. Luminescence sensitivities of quartz grains from eolian deposits in northern China and their implications for provenance. *Quaternary Research* 76 (2), 181–189. DOI: 10.1016/j.yqres.2011.06.015

Mauz B., Bode T., Mainz E., Blanchard H., Hilger W., Dikau R., Zöller L. 2002. The luminescence dating laboratory at the University of Bonn: Equipment and procedures. *Ancient TL* 20, 53–61.

Pál-Molnár E., Batki A., Ódri Á., Kiss B., Almási E. 2015. Geochemical implications for the magma origin of granitic rocks from the Ditrău Alkaline Massif (Eastern Carpathians, Romania). *Geologia Croatica* 68 (1), 51–66. DOI: 10.4154/GC.2015.04

Pietsch T. J., Olley J. M., Nanson G. C. 2008. Fluvial transport as a natural luminescence sensitiser of quartz. *Quaternary Geochronology* 3 (4), 365–376. DOI: 10.1016/j.quageo.2007.12.005

Preusser F., Ramseyer K., Sclücheter C. 2006. Characterisation of low OSL intensity quartz from New Zealand Alps. *Radiation Measurements* 41 (7-8), 871–877. DOI: 10.1016/j.radmeas.2006.04.019

Preusser F., Makaiko L. Chithambo, Götte T., Martini M., Ramseyer K., Sendezera J. E., Susino J. G., Wintle A. G. 2009. Quartz as a natural luminescence dosimeter. *Earth-Science Reviews* 97 (1), 184–214. DOI: 10.1016/j.earscirev.2009.09.006

Rendell H. M., Webster S. E., Sheffer N. L. 1994. Underwater bleaching of signals from sediment grains: New experimental data. *Quaternary Science Reviews* 13 (5-7), 433–435. DOI: 10.1016/0277-3791(94)90055-8

Sawakuchi A. O., Blair M. W., DeWitt R., Faleiros F. M., Hyppolito T. N., Guedes C. C. F. 2011. Thermal history versus sedimentary history: OSL sensitivity of quartz grains extracted from rocks and sediments. *Quaternary Geochronology* 6, 261–272. DOI: 10.1016/j.quageo.2010.11.002

Sawakuchi A. O., Guedes C. C. F., DeWitt R., Giannini P. C. F., Blair M. W., Nascimento Jr. D. R., Faleiros F. M. 2012. Quartz OSL sensitivity as a proxy for storm activity on the southern Brazilian coast during the Late Holocene. *Quaternary Geochronology* 13, 92–102. DOI: 10.1016/j.quageo.2012.07.002

Sawakuchi A. O., Jain M., Mineli T. D., Nogueira L., Bertassoli Jr. D. J., Häggi C., Sawakuchi H. O., Pupi F. N., Grohmann C. H., Chiessi C. M., Zabel M., Mulitza S., Mazoca C. E. M., Cunha D. F. 2018. Luminescence of quartz and feldspar fingerprints provenance and correlates with the source area denudation in the Amazon River basin. *Earth and Planet. Sci. Lett*. 492, 152–162. DOI: 10.1016/j.epsl.2018.04.006

Sawakuchi A. O., Rodrigues F. C. G., Mineli T. D., Mendes V. R., Melo D. B., Chiessi C. M., Giannini P. C. F. 2020. Optically Stimulated Luminescence Sensitivity of Quartz for Provenance Analysis. *Methods and Protocols* 3 (1), 6. DOI: 10.3390/mps3010006

Schumm, S. A. 1979. Geomorphic thresholds: the concept and its applications. *Transactions of the Institute of British Geographers* 4 (4), 485–515. DOI: 10.2307/622211

Sharma S. K., Chawla S., Sastry M. D., Gaonkar M., Mane S., Balaram V., Singhvi A. K. 2017. Understanding the Reasons for Variations in Luminescence Sensitivity of Natural Quartz Using Spectroscopic and Chemical Studies. *Proceedings of the Indian National Science Academy* 83 (3), 645–653. DOI: 10.16943/ptinsa/2017/49024

Silye L. 2015. Sarmatian foraminiferal assemblages from southern Transylvanian Basin and their significance for the reconstruction of depositional environments. Cluj-Napoca: Presa Universitară Clujeană. ISBN: 978-973-595-852-7

Sipos Gy., Kiss T., Tóth O. 2016. Constraining the age of floodplain levels along the lower section of river Tisza, Hungary. *Journal of Environment Geography* 9 (1-2), 39–44. DOI: 10.1515/jengeo-2016-0006

Urdea P., Sipos Gy., Kiss T., Onaca A. 2012. The Maros/Mureş (A Maros) In: Sipos. Gy. (ed.) Past, Present, Future of the Maros/Mureş River. (A Maros folyó múltja, jelene, jövője). Szegedi Tudományegyetem, Természeti Földrajzi és Geoinformatikai Tanszék, Universitatea de Vest din Timişoara, Departamentul de Geografie. 159–167

Smedley R. K., Buylaert J.-P., Ujvari G. 2019. Comparing the accuracy and precision of luminescence ages for partially bleached sediments using single grains of K-feldspar and quartz. *Quaternary Geochronology* 53, 101007. DOI: 10.1016/j.quageo.2019.101007

Tóth O., Sipos G., Kiss T., Bartyik T. 2017. Variation of OSL residual doses in terms of coarse and fine grain modern sediments along the Hungarian section of the Danube. *Geochronometria* 44 (1), 319–330. DOI: 10.1515/geochr-2015-0079

Walling D. E. 2013. The evolution of sediment source fingerprinting investigations in fluvial systems. *Journal of Soils Sediments* 13, 1658–1675. DOI: 10.1007/s11368-013-0767-2

Wintle A. G., Murray A. S. 2006. A review of quartz optically stimulated luminescence characteristics and their relevance in single-aliquot regeneration dating protocols. *Radiation Measurements* 41, 369–391. DOI: 10.1016/j.radmeas.2005.11.001

Wintle A. G., Adamiec G. 2017. Optically stimulated luminescence. Radiation Measurements signals from quartz: A review. *Radiation Measurements* 98, 10–33. DOI: 10.1016/j.radmeas.2017.02.003

Zheng C. X., Zhou L. P., Qin J. T. 2009. Difference in luminescence sensitivity of coarse-grained quartz from deserts of northern China. *Radiation Measurements* 44 (5-6), 534–537. DOI: 10.1016/j.radmeas.2009.02.013