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Moritz Nykamp – Bernhard S. Heeb – Daniel Knitter – Jan Krause – Rüdiger Krause – Alexandru Szentmiklosi – Brigitta Schütt

Linking Hydrological Anomalies to Archaeological Evidences – Identification of Late Bronze Age Pathways at the Fortification Enclosure Iarcuri in Western Romania

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Moritz Nykamp – Bernhard S. Heeb – Daniel Knitter – Jan Krause – Rüdiger Krause – Alexandru Szentmiklosi – Brigitta Schütt

Linking Hydrological Anomalies to Archaeological Evidences – Identification of Late Bronze Age Pathways at the Fortification Enclosure Iarcuri in Western Romania

For the environs of the Late Bronze Age fortification enclosure Iarcuri the hydro-morphological relief characteristics are combined with archaeological evidences. Target of the study is to evaluate the impact of settlement activities in the surroundings of Iarcuri on the development of the channel network. Data analysis is based on topographic map-derived and high resolution DEMs provided by LiDAR scanning; derivatives of the DEMs are used to characterize the different sub-catchments that show varying influences by the fortification ramparts. The tributaries reaching the receiving stream close to the central settlement area source close to the gates in the ramparts in the Late Bronze Age built-up areas. Additionally, also the geometry of these tributaries differs from that of other tributaries. The distinct character of the channel network with repeatedly occurring rectangular bends indicates the capture of channels, which developed as gullies along paths by retrogressive erosion.

Hollow ways; morpho-hydrological relief characteristics; human impact on drainage network development; settlement patterns; landscape archaeology.

1 Introduction

Consisting of four earth-filled wooden ramparts with a total length of more than 33 km the Late Bronze Age fortification enclosure Iarcuri covers a surface of more than 17.2 km^2. It is situated at the eastern edge of the Great Hungarian Plain and represents the largest prehistoric settlement in Europe known so far. What is known after seven years of excavation and survey is that Iarcuri is a fortified settlement from the Late Bronze Age (Cruceni-Belegiş culture).[1] There are rough ideas on the areas intra muros that were built-up and the density of the population.[2] Unknown so far is the reason that a settlement of that size and structure was built in this landscape and what kind of society was powerful enough to impose and organize the construction of those ramparts and how

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1 Heeb, Szentmiklosi, and Wiecken 2008, 185; Szentmiklosi et al. 2011, 827–828; Heeb et al. 2012, 47 and 49–52; Heeb, Jahn, and Szentmiklosi 2014, 85–86.

2 Heeb et al. 2012, 56.

their economic foundation looked like.[3] Likewise, it remains unclear what impacts the fortification enclosures and the economic actions that are mandatory to supply such a society had on the natural environment. Certain archaeological questions can only be fully answered in cooperation with earth sciences and, in turn, some findings obtained applying methods from earth sciences can only be interpreted integrating archaeological findings. Hence, a landscape archaeological approach[4] is applied in order to avoid the gap between sciences and humanities.

The objective is to relate archaeological evidences from the Late Bronze Age fortification enclosures and the settlement areas to the morphological and hydrological characteristics of its environs. We hypothesize that the activities within and around the Late Bronze Age fortification significantly affected the development of the relief and caused varied morpho-hydrological particularities. In order to test our hypothesis digital elevation models (DEMs) are used to compare different basins. Archaeological evidences are linked to LiDAR-based DEM derivatives to explain the formation of the morpho-hydrological anomalies.

1.1 Study site

The archaeological site Corneşti-Iarcuri is located in the Romanian Banat, about 20 km north of Timişoara. As a part of the Vinga Plain, the environs of Iarcuri are part of the west Romanian high piedmont plain (Fig. 1).[5] A moderate temperate climate, with annual mean precipitation of 550 mm and a potential evapotranspiration of about 700 mm prevails on the Vinga Plain.[6] Geologically, the Vinga Plain is built up by a mixture of Early to Late Pleistocene gravels, sand and clay.[7] During the Quaternary the area was covered by loess and loess-like deposits. The soils that developed in these aeolian sediments are characteristically Chernozems and Phaeozems. Variations that occur mainly due to relief differences include eroded Chernozems at the hillslopes, colluvisols at the footslopes and fluvic-gleyic Chernozems in the alluvial plains. The alignment of the mainly northeast-southwest oriented valleys is determined by the slight southwest dipping of the Vinga Plain (Fig. 1).[8] Two creeks that flow in wide saucer-shaped valleys cross the archaeological site from northeast to southwest (Fig. 2).[9]

The relief in the surroundings of Iarcuri is composed of two general units: the high plain and the intersecting valleys. The high plain consists of wide, slightly undulating interfluves that decline from 170 m a.s.l. in the northeast to 130 m a.s.l. in the southwest (Fig. 2a). It's slopes incline between 0° and 2°, only locally reaching up to 5° like in the northern part of enclosure III (Fig. 2b). The two main valleys that dissect the high plain run in northeast-southwest direction. Numerous hollows and first order tributaries occur alongside these valleys. The course of some of these tributaries bends in an almost right angle and locally runs against the general surface gradient (Fig. 2a). The transition between the high plain and the valleys is usually marked by a shoulder with a distinct convex profile-curvature. At the shoulder inclinations increase up to 5° to 10°. Inclinations of 10° to 18°, locally increasing up to 22.5°, and mainly straight profile-curvatures characterize the midslope sections. At the footslopes, in the transition zone to the alluvial plains,

3 This represents the superordinate goal of the ongoing international archaeological project carried out since 2007.
4 Kluiving, Lehmkuhl, and Schütt 2012, 2.
5 Badea, Niculescu, and Sencu 1979.
6 Grigoraş, Piciu, and Vlăduţ 2004, 35.
7 Institutul Geologic 1966; Borsy 1990, 234.
8 Grigoraş, Piciu, and Vlăduţ 2004, 33–34, 35–38.
9 Micle, Măruia, and Dorogostaisky 2006, 285.

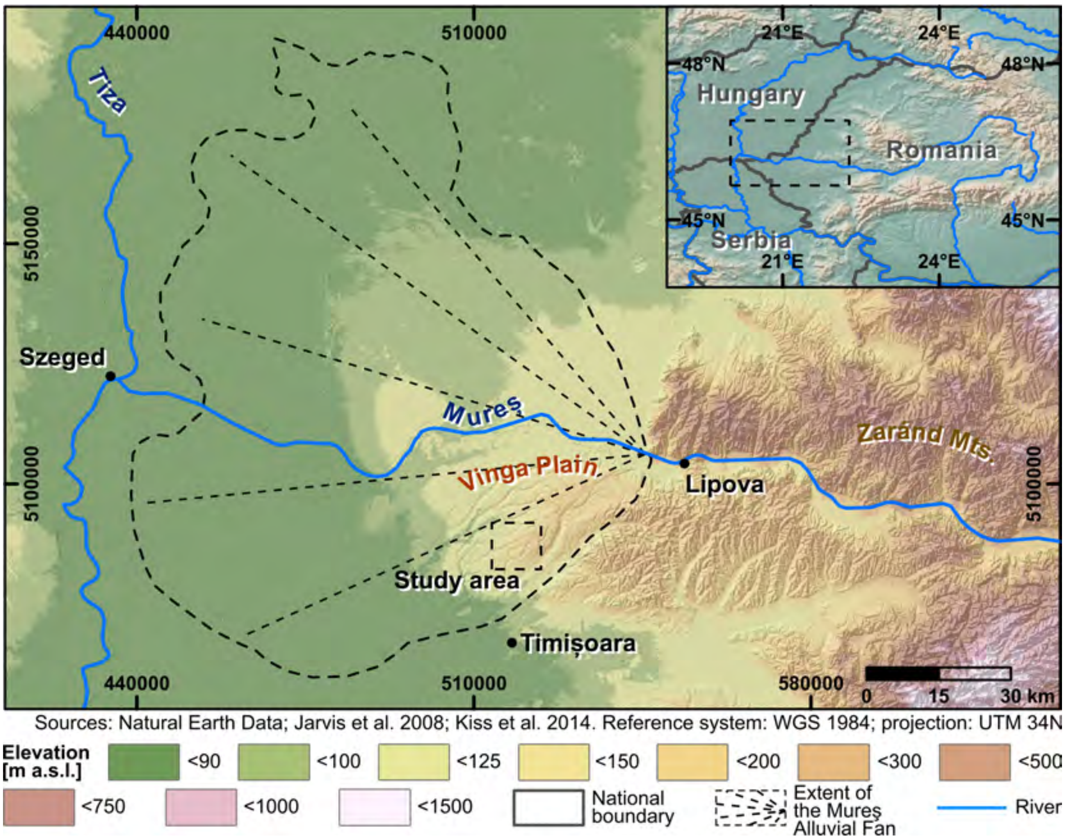

Fig. 1 | Overview map of the study area showing the location of the archaeological site Corneşti-Iarcuri on the Vinga Plain and the approximate extension of the Late Quaternary Mureş fan.

the inclinations decrease to 2° to 5° and profile-curvatures become slightly concave. The alluvial plains are flat (0° to 2°) and relatively narrow. They only widen locally, e. g. in the central part of the second enclosure (Fig. 2b, c).

The four earth-filled wooden ramparts of Iarcuri are numbered I to IV from inside out. The innermost rampart I (Fig. 2a) is nearly circular, has a diameter of approximately one kilometer and is situated on the plateau between the Carani and the Lake valley. With respect to the sense of a fortification the situation of rampart I seems to be consequent. Rampart II has an elliptic shape with a north-south running length axis. In its run it crosses both, the Carani and the Lake valley twice. At the present state of knowledge it is not possible to reconstruct whether the interruptions by the two valleys were closed during the settlement period or not. Rampart III has the same oval, north-south elongated shape as the rampart II. Its course follows the divide of the Carani valley in the north and runs across the wide plateau divide between the Lake and Vineyard valley in the south. Rampart IV is northeast-southwest elongated and almost encloses the entire catchment of the Lake valley (Fig. 2a). All four ramparts show defensive ditches in front of the ramparts and rearward depressions from where construction material was extracted.

The site of Iarcuri is the largest prehistoric settlement known by today. It dates to the Late Bronze Age, however, its settlement history starts already in the Copper Age (Tiszapolgár culture) around 4000 BC.[10] The Copper Age finds originate from inside of the ramparts I and II. They do not occur area-covering, but locally lumped in the form of different kinds of settlements like homesteads and a village. The four ramparts all date

10 Szentmiklosi et al. 2011, 832; Heeb et al. 2012, 50–51.

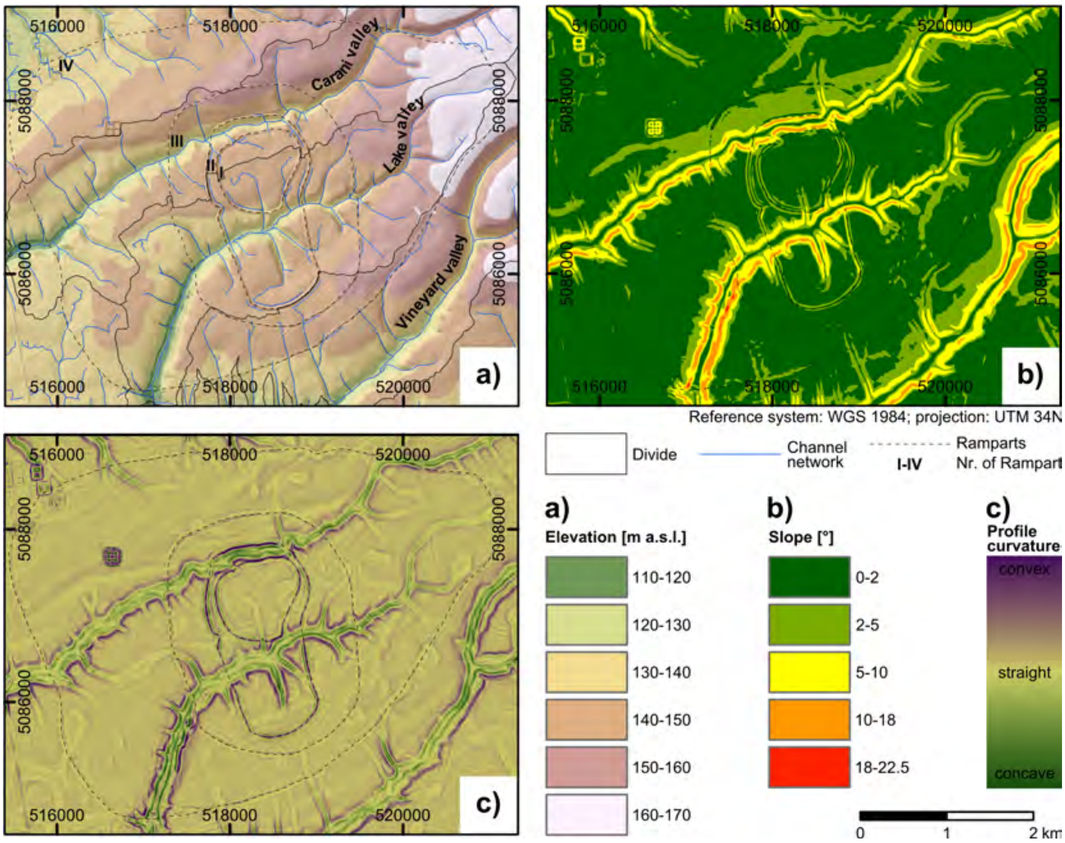

Fig. 2 | Detailed maps of the study site. Surface elevation (a), slope gradient (b) and profile curvature (c). The dashed lines in the maps mark the location of the four enclosing ramparts of Iarcuri.

back to the Late Bronze Age and are not linked to the Copper Age settlements. Rather, the Copper Age settlements are followed by a long hiatus that occurs until the Middle Bronze Age (Vattina culture). What happened during Middle Bronze Age remains widely unclear. It is assumed that a loose occupation with pit dwelling houses existed inside the second rampart,[11] forming the nucleus for the big Late Bronze Age settlements. Since 2007 areas inside the ramparts I and II and segments of the ramparts I, II and IV had been excavated. The whole first rampart and large parts inside rampart II have been surveyed by magnetic prospections and field walking (Fig. 3).[12]

2 Methods

2.1 Geography

A digital elevation model (DEM) of the wider area of Iarcuri is created by applying the TOPOGRID[13] algorithm to the digitized contour lines of the topographic map[14] (1:25,000). Drainage divides and ordered[15] drainage networks are derived using an A^T least-cost

11 Heeb et al. 2012, 53–54.
12 Szentmiklosi et al. 2011, 823-827; Heeb et al. 2012, 53–56; Heeb, Jahn, and Szentmiklosi 2014, 85–86.
13 Hutchinson 1989.
14 Direcţia Topografică Militară 1982.
15 Strahler 1957, 914.

search algorithm.[16] Based on this the basin size and drainage density[17] are calculated for the basins. First and second order tributaries that directly drain into the main channel are counted and the frequency of tributaries per kilometer of the main channel course is recorded. The ratio between length of the flow path and the distance from the source to the mouth[18] of the tributaries is used to distinguish between the straight, slightly bending and bending courses. The basin of the Lake valley is compared to neighboring third order basins: while the Lake valley is almost entirely surrounded by the four ramparts of Iarcuri and therefore, represents an area highly affected by settlement activities. The neighboring third order basins are more or less unaffected by prehistoric settlement activities. The basins to be compared with the Lake valley basin are chosen due to their order, size and proximity to site of Iarcuri.

Morphometric and hydrological analyses are conducted on a LiDAR-based DEM. Initial DEM processing comprises smoothing and resampling. To reduce the noise of the surface elevation that is caused by the high ground resolution of the LiDAR data (initially 0.5 by 0.5 m^2) a large moving window (69 by 69 cells) was applied for smoothing.[19] A pixel resampling to a resolution of 1 by 1 m^2 was done in order to reduce the impact of very small artificial features like furrows. The processed DEM is used to derive the slope angle and the profile curvature using a moving window of 11 by 11 cells.[20] The drainage divides and ordered[21] stream segments are deduced applying an A^T least-cost search algorithm to the LiDAR DEM.[22] The DEM derivatives were used to characterize the relief and the stream network morphometrically. The geometry of all tributaries that contribute to the creeks in the Carani and Lake valley was assessed using the flow path length to distance-ratio.[23]

2.2 Archaeology

Beside excavations, large scale systematic field walking and geophysical prospections were applied (Fig 3). Between 2007 and 2012 the focus of excavation was on how the ramparts were constructed and how they are dating. From 2013 onwards the research concentrated on the investigation of the settlement areas within the ramparts I and II. The trenches cutting the ramparts (so far ring I, II and IV) are long and narrow (2008: 80 by 5 m^2) documenting the rampart and the adjoining defensive ditches in front and structures behind.[24]

Gates in the ramparts were localized through an integrated application of excavation, magnetic prospections and LiDAR DEM-based mapping. The parameters that define a gate are the evidence achieved by excavation, a gap in the ramparts that is visible on the surface and the interruption of the rampart and the defensive ditch as verified through the magnetic prospections.

16 Ehlschlaeger 1989; Jasiewicz and Metz 2011.
17 Leopold, Wolman, and Miller 1995, 142.
18 Ahnert 2003, 222.
19 Wood 1996.
20 Wood 1996.
21 Strahler 1957, 914.
22 Ehlschlaeger 1989; Jasiewicz and Metz 2011.
23 Ahnert 2003, 222.
24 Szentmiklosi et al. 2011; Heeb et al. 2012; Heeb, Jahn, and Szentmiklosi 2014, 85–86.

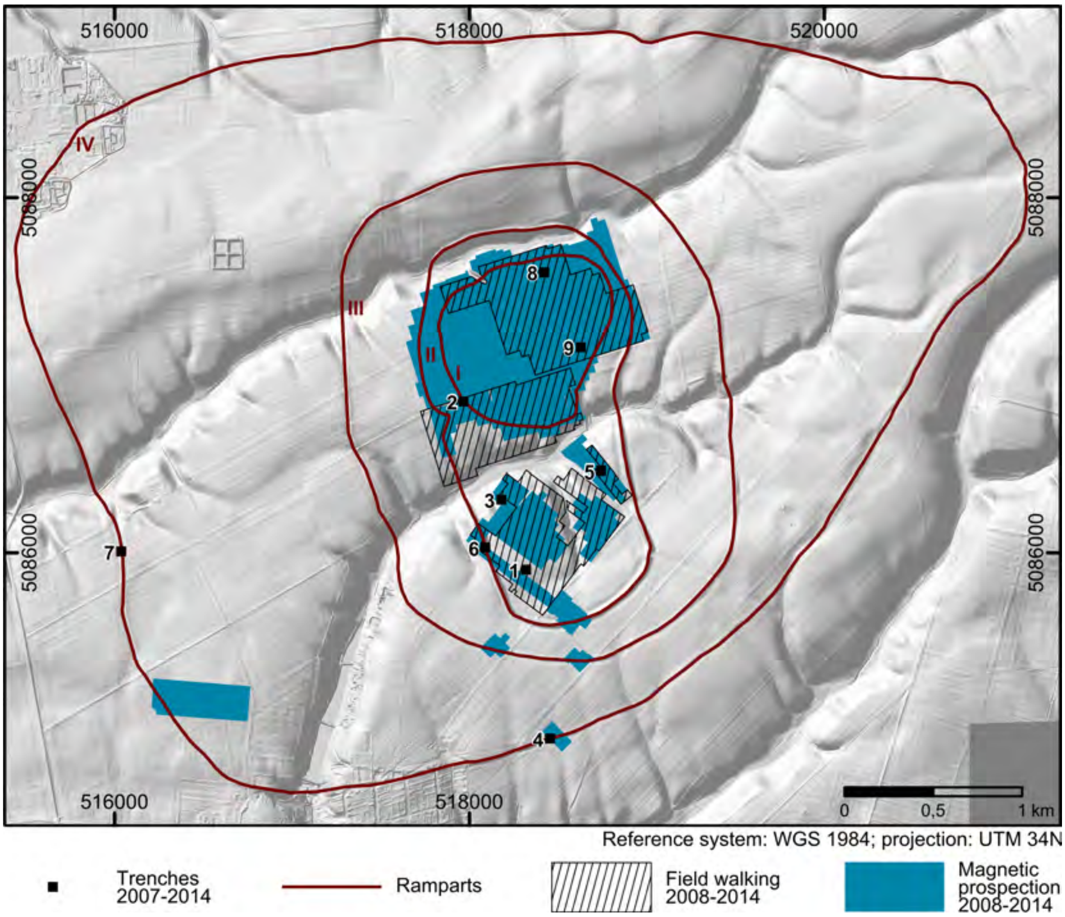

Fig. 3 | Locations of the excavations 2007–2014, field walking areas 2008–2014 and magnetic prospection areas 2008–2014 within the ramparts of Iarcuri.

3 Results

3.1 Geography

The fortification enclosures of Iarcuri lie almost entirely within basin 1 (Fig. 4). Basin 1 has a size of 7.44 km^2 and a drainage density of 1.93 km*km^{-2}. Along the six kilometers of the run of the receiving stream a total of 14 tributaries drain into it; the frequency of tributaries per kilometer of the main channel totals 2.33. A total of nine (64.29 %) of these tributaries are straight, the course of three (21.43 %) tributaries is slightly bending and the course of two (14.29 %) tributaries is strongly bending (Fig. 4).

Small parts of basin 2 are located in the built-up area of Iarcuris' rampart IV. Basin 2 covers an area of 8.31 km^2 and it has a drainage density of 2.07 km*km^{-2}. The main channel has a length of 6.51 km and twelve tributaries drain into it; a tributary frequency of 1.84 per kilometer is resulting. Regarding the form of the tributaries it turns out that ten of them (83.33 %) are straight and two (16.67 %) are slightly bending (Fig. 4).

Basin 3 lies outside the built-up environment of Iarcuri. It covers an area of 8.67 km^2, has a drainage density of 1.49 km*km^{-2} and its receiving channel is 6.53 km long. Twelve tributaries drain into the receiving channel, consequently the tributary frequency per kilometer totals 1.84. Eleven (91.67 %) of the tributaries have a straight course and one (8.33 %) has a slightly bending course (Fig. 4).

Basin 4 is with an area of 5.71 km^2 the smallest of the four catchments. As basin 3, it lies outside the direct influence of the constructed area of Iarcuri. Its drainage density is

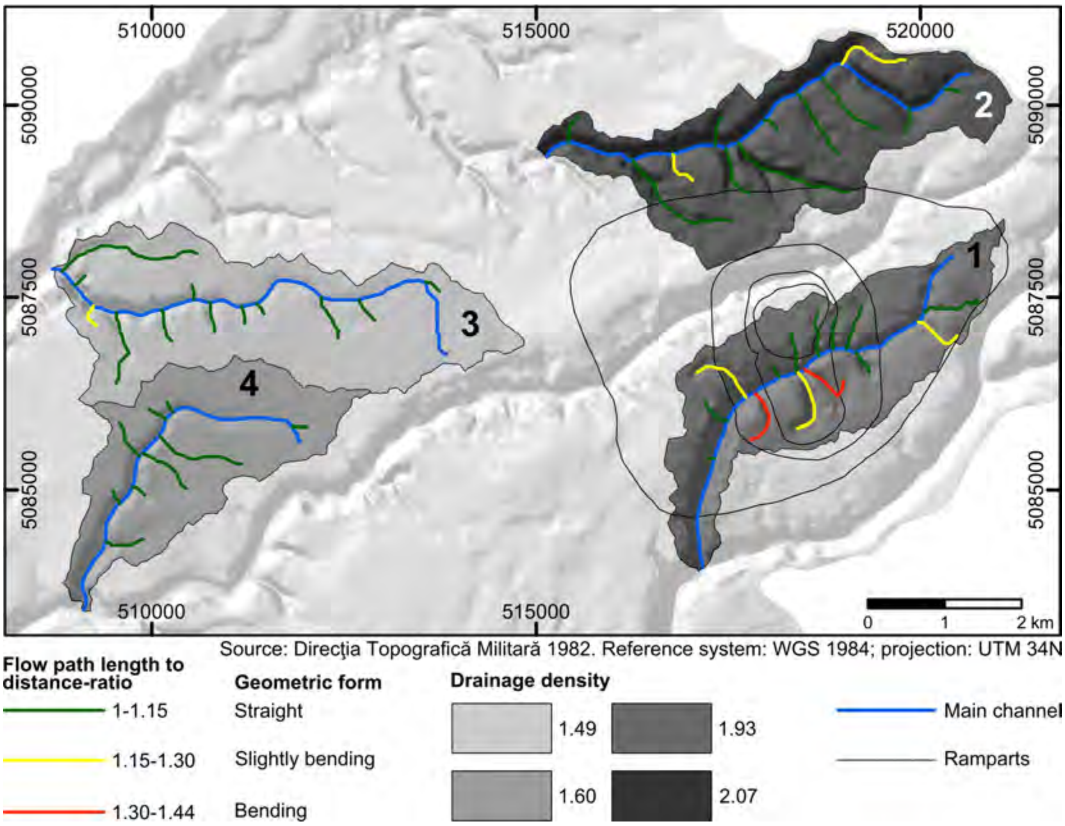

Fig. 4 | Hydrological characteristics of selected third order basins in the wider surroundings of Iarcuri based on the topographic map-derived DEM.

1.6 km*km^{-2} and its main channel has a total length of 4.88 km. Nine tributaries drain into the receiving channel (frequency: 1.84) and all of them are straight (Fig. 4).

The comparison of the four neighboring third order catchments reveals that the basins 1, 2 and 3 are rather similar with respect to basin size (mean: 7.53, STD: 1.32) and length of the main channel (mean: 5.98, STD: 0.77), whereas basin 4 is smaller and has a shorter main channel. In terms of the drainage density (mean: 1.77, STD: 0.27) the basins 1 and 4 are comparable, while basin 2 shows a higher and basin 3 a lower drainage density. Focusing on the character of the tributaries it turns out that in basin 1 the number and frequency of tributaries that drain into the receiving channel is higher than in the other basins (mean: 1.96, STD: 0.25). Comparing the overall frequency of the straight, slightly bending and bending channel courses it becomes evident that the straight running tributaries are fairly even distributed between the four basins (between 23 and 28 %). The distribution of the tributaries with slightly bending and bending courses is, in contrast to that, rather unequally distributed: 50 % of the slightly bending tributaries occur in basin 1 while the other half is located in basin 2 (33.33 %) and basin 3 (16.67 %). Moreover, it turns out that all of the distinctly bending tributaries are located in basin 1 (Fig. 4).

Since the high resolution digital elevation model based on LiDAR data is exclusively available for the site of Iarcuri it is not possible to work with it on a catchment scale. However, the data show that 18.75 % of the tributaries that contribute to the Carani and Lake valley within the built-up area of Iarcuri show direct connections to the construction of the ramparts. These tributaries are located directly in front or rearwards of the ramparts. At the same positions defensive ditches had been created, or material for the construction of the ramparts had been extracted, respectively. Additionally, differences regarding the tributaries within the built-up environment of Iarcuri exist as well. While the frequency of tributaries is higher in the catchment of the Carani creek, the Lake valley shows more bending tributaries (Fig. 5). The course of the Carani creek within the site of Iarcuri has a length of 5.36 km and a total of 24 tributaries drain into it. The resulting frequency of tributaries per kilometer main channel totals 4.48. The evaluation of the flow path to distance-ratio shows that 22 (91.67 %) of the tributaries have a straight course, one (4.17 %) has a slightly bending and one (4.17 %) has a distinctly bending course (Fig. 5). The main channel of the Lake valley has a length of 6.35 km and 24 tributaries drain into it. The frequency of tributaries per kilometer of the receiving channel totals 3.78. With respect to their form the results from the Lake valley show that 19 (79.17 %) of the tributaries have a straight course, two (8.33 %) have a slightly bending and three (12.50 %) have a distinctly bending course (Fig. 5).

Comparing the areas within the built-up environment of Iarcuri it turns out that 75 % of the tributaries with distinctly bending course and 66.67 % of those with slightly bending course occur in the Lake valley, which crosses the site of Iarcuri in the central position between the ramparts I and II (Fig. 5).

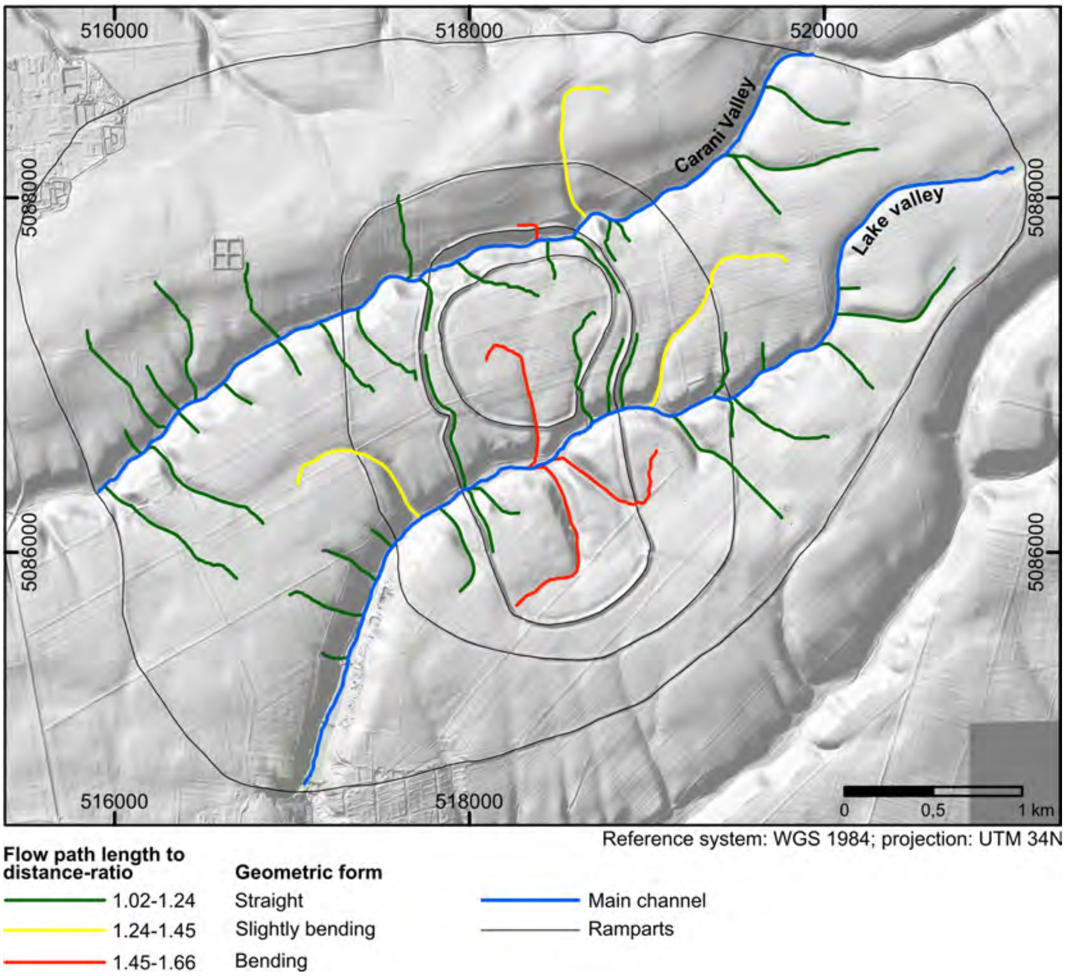

Fig. 5 | Flow path length to distance-ratio of the tributaries in the Carani and Lake valley.

3.2 Archaeology

Archaeological investigation of the Iarcuri fortification took place in four different trenches: one trench each was dug in rampart I and II and in IV two trenches were dug. Ceramics or other finds are rather rare in the ramparts, thus dating is based on ^{14}C samples. Based on this it gets evident that all four ramparts date into the Late Bronze Age. Though the ramparts I and II seem to be the oldest (c. 1500 to 1300 cal. BCE/3450 to 3250 cal. BP) and rampart IV attends to be a bit younger (1300 to 1000 cal. BCE/3250 cal. BP to 2950 cal. BP).[25] Slight differences in construction can be detected, but whether this is suitable for a chronological difference remains unclear so far.

The excavation of a gate in rampart IV shows a bridgehead, an element of fortification that had been up to this point earliest known from Roman times.[26] It is so far the only excavated Late Bronze Age passage of the ramparts in Iarcuri; others have been surveyed by magnetic prospections[27] or by satellite images.[28] A total of ten gates have been verified until now (Fig. 6).

In wide areas inside the ramparts I and II magnetic anomalies are measured, which in parts surely indicate houses and developed areas. By now it seems that the buildings inside rampart I are mostly located in the northeastern part (Fig. 6). Inside rampart II the magnetic prospection is still in process. However, preliminary results show that large areas must have been covered by houses and huts. In 2013 remains of at least four Late Bronze Age houses inside rampart I were uncovered in an 800 m^2 large trench, though their chronological relations are not clarified yet. In 2014 a circular v-shaped ditch with a diameter of approx. 25 m and at least one Copper Age house within was discovered.

Since 2008 a total 1.17 km^2 of systematic field walking and 1.56 km^2 of magnetic prospections had been carried out. Until 2014 a surface of 0.84 km^2 was surveyed by both methods so that the results can be combined. By that we suppose that most magnetic anomalies inside the ramparts I and II are likely from Late Bronze Age, except some Middle Bronze Age and Copper Age structures. The number and kind of Late Bronze Age finds collected from the surface give a first idea about the density of inhabitation and the usage of these areas. Inside rampart II nearly double the amount of finds (mostly sherds and daub) were recovered from an area of the same size as in rampart I. That likely indicates a denser occupation in ring II. Quern stones are even more common in ring II, which might indicate that grain processing was mostly carried out in this area (Fig. 6).

4 Discussion

The characterization of the four drainage basins in the vicinity of the archaeological site Iarcuri shows significant differences regarding their drainage densities and tributary frequencies as well as in terms of tributary geometry. As due to their spatial proximity within the identical geomorphic unit of the Vinga Plain the prevailing local climate is regarded to be uniform across the four catchments,[29] climatic and geomorphological conditions can be neglected to explain the observed differences. Solely, tectonic activity due to varying subsidence[30] might also be a natural reason for the different catchment characteristics, but due to the proximity of the four basins this factor is also ignored.

25 Szentmiklosi et al. 2011, 823–828; Heeb et al. 2012, 54–55.
26 Heeb, Jahn, and Szentmiklosi 2014, 85–86.
27 Szentmiklosi et al. 2011, 829–831; Heeb et al. 2012, 51–54.
28 Heeb, Szentmiklosi, and Wiecken 2008, 181.
29 Grigoraş, Piciu, and Vlăduţ 2004, 35.
30 Urdea et al. 2012, 160.

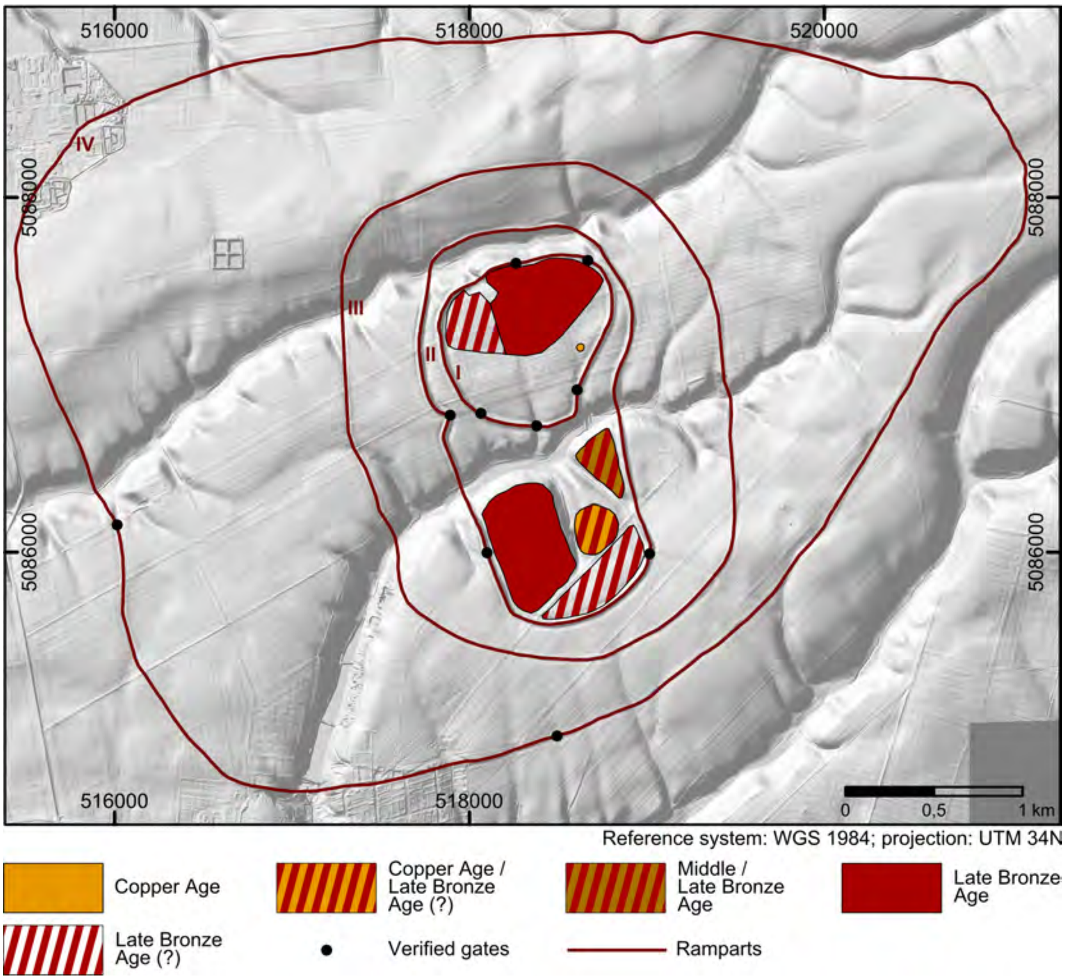

Fig. 6 | Archaeological map indicating the locations of the verified gates and the settled areas between the Copper Age and Late Bronze Age.

The geological underground, consisting of Pleistocene gravel, sand and clay[31] that were covered with Pleistocene loess,[32] as well as the soils, mostly consisting of chernozemic Mollisols[33] can also be ruled out causing the observed differences between the catchments. Both, the parent material and the soils that have developed within, are rather uniform and are unrelated to the varying drainage densities as well as the geometric character of the tributary channels. Consequently, past settlement activities around Iarcuri are assumed as the driving force in the development of the channel network as documented for various archaeological sites and elsewhere.[34] The concentrated appearance of bending tributaries, partially showing reaches with a reversed gradient, indicates that settlement activities in Iarcuri fostered the development of channels, e. g. in the context of gully erosion along paths.[35]

The two catchments that are directly influenced by the ramparts show distinctly higher drainage densities than the two catchments beyond the built-up area. The higher

31 Institutul Geologic 1966; Borsy 1990, 234.
32 Grigoraş, Piciu, and Vlăduţ 2004, 34.
33 Florea et al. 1979; Grigoraş, Piciu, and Vlăduţ 2004, 41.
34 Hempel 1957, 11–12; Denecke 1969, 145–147; Gregory and Park 1976, 82; Tsoar and Yekutieli 1992, 213–215; Wilkinson 1993, 548–549; Ur 2003, 109–112; Wilkinson et al. 2010, 745–746.
35 Hempel 1957, 30–31; Brice 1966, 313; Piest and Ziemnicki 1979, 822 and 826–827; Tsoar and Yekutieli 1992, 213; Wilkinson 1993, 550; D. Hassler and M. Hassler 1993, 68–69.

frequency of tributaries in basin 1 documents the intensive dissection of the valley flanks in this catchment; at least also documenting gullying processes in an intensively used area.[36] The location of the tributaries to be related to former gullies linking between the receiving channels and the ramparts emphasizes that gullying took place along the path system.[37] Also the course character of the tributaries documents their origin by path-oriented gully erosion: the bending tributaries concentrate on the basin surrounded by the ramparts.[38]

The analysis of the high resolution LiDAR DEM documents that almost 20 % of the tributaries inside the built-up environment of Iarcuri source at the ramparts. It is pointed out that the Carani and the Lake valley differ distinctly with respect to their tributaries' frequencies and geometries. Two thirds of the moderately bending and three quarters of the bending tributaries are located in the Lake valley drainage basin. The bending tributaries concentrate in the central part of the Lake valley basin within rampart II. The archaeological map reveals that the Late Bronze Age settlements are concentrated in two areas within the ramparts I and II. By comparing the locations of the Late Bronze Age settlements and the position of the southern gate in rampart I with the location of the three neighboring bending tributaries it appears that both are related.

Typical linear features in landscapes are paths, which develop in consequence of the repeated passage of humans and animals.[39] Due to compaction processes along the paths they serve as drainage pathways during rainfall events, after a while forming linear hollows, also named sunken lanes or hollow ways, which were formed in association with archaeological sites and contemporaneously with the occupation period of the site.[40] The compacted soil tends to reduced water infiltration rates and accelerated surface runoff that leads to soil erosion[41] and hence, the initiation and lowering of a hollow way. Wilkinson describes forms of hollow ways in Mesopotamia that are identical to those observed in the vicinity of the archaeological site of Iarcuri. He observed that hollow ways partially became a part of the main channel or of a minor tributary, but elsewhere they clearly run discordant to the natural drainage system, cross watersheds or had reaches with a reversed gradient.[42] Tsoar and Yekutieli present in their study on ancient paths in the loess landscape of the Northern Negev examples of path-oriented gullies that at some point bend and form a distinct right angle as it is the case for several tributaries in the built-up environment of Iarcuri. They argue that the retrogressive erosion of path-oriented gullies captured minor tributaries or older hollow ways with a completely different orientation.[43] The formation of most of the bending and slightly bending tributaries that occur in the settlement area of Iarcuri can be explained with the capture of former hollow ways by minor tributaries of the Carani and Lake valleys, especially in situations where the reaches of the tributaries flow in the reverse direction to the general surface gradient. The fact that certain tributaries can be associated with the verified gates or the settlements within the Late Bronze Age fortification suggests that they formed during the same period as hollow ways.

36 Brice 1966, 313; Piest and Ziemnicki 1979, 822.

37 Wilkinson 1993, 548; M. Hassler and D. Hassler 1993, 83–85; Ur 2003, 109–112; Wilkinson et al. 2010, 763–767.

38 Hempel 1957, 30–31; Tsoar and Yekutieli 1992, 213.

39 Brice 1966, 313; Denecke 1969, 40–44; Piest and Ziemnicki 1979, 826–827; Tsoar and Yekutieli 1992, 209; Wilkinson 1993, 548; Ur 2003, 102; Wilkinson et al. 2010, 763–767.

40 Wilkinson 1993, 552–553.

41 Goudie 2006, 105–106.

42 Wilkinson 1993, 550.

43 Tsoar and Yekutieli 1992, 212–213.

5 Conclusions

The study shows that the fortification enclosures of Iarcuri influenced the development of the drainage system in its immediate environment. Moreover, the analyses reveal that the bending side channels occur clustered in the central part of the Lake valley and in association with the Late Bronze Age settlements and certain verified gates in the ramparts. The association of the Late Bronze Age structures with the unnaturally bending channels suggests that the channels developed during the time period when the site was occupied. Path formation due to trampling by moving humans and animals fostered the development of gullies and linear hollows. Whether the channel geometry could be used to localize additional gates in the fortification enclosures is an issue of future research.

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Moritz Nykamp
M.Sc., is physical geographer and since 2012 employed as a scientific assistant at the Institute of Geographical Sciences, Freie Universität Berlin. Since 2013 he is a PhD student in Landscape Archaeology and Architecture at the BerGSAS. His main research interests are landscape archaeology, human-environmental interactions, landscape development and paleoenvironmental reconstruction.

Moritz Nykamp
Freie Universität Berlin
Institute of Geographical Sciences, Physical Geography
Malteserstraße 74–100
12249 Berlin, Germany

E-Mail: m.nykamp@fu-berlin.de

Bernhard S. Heeb
is archaeologist with a scientific focus on Late Bronze Age in southeast Europe. He is curator at the Museum for Pre- and Early History in Berlin for Bronze Age, Troy, Cyprus and the anthropological collection. He obtained his PhD in 2009 at the Johann Wolfgang Goethe-Universität Frankfurt am Main.

Dr. Bernhard S. Heeb
Museum für Vor- und Frühgeschichte
Staatliche Museen zu Berlin – Stiftung Preußischer Kulturbesitz
Archäologisches Zentrum
Geschwister-Scholl-Straße 6
10117 Berlin, Germany

E-Mail: b.heeb@smb.spk-berlin.de

Daniel Knitter
2013 obtained his doctorate in Berlin on "Central Places and the Environment – Investigations of an Interdependent Relationship"; M.Sc. and B.Sc. in Geography; since 2013 scientific assistant and Topoi Lab coordinator of research area A within *Excellence Cluster Topoi*; 2009–2010: Research assistant in *Topoi*, research group "Monti Navegna e Cervia" (A-I-9); Research interests: Human-environmental interactions, especially in connection with geomorphological and geomorphometrical process and (pre)historic landscape development under human influence; theoretical geography.

Dr. Daniel Knitter
Freie Universität Berlin
Institute of Geographical Sciences, Physical Geography
Malteserstr. 74–100
12249 Berlin, Germany

E-Mail: daniel.knitter@topoi.org

Jan Krause
Dr. rer.nat. (FU Berlin 2013), since 2003 research assistant, Institute of Geographical Sciences, Freie Universität Berlin, and since 2008 project coordinator of Research Area A in the *Excellence Cluster Topoi*. Research interests: GIS, palaeohydrology, past and present morphodynamics, drylands, landscape archaeology.

Dr. Jan Krause
Freie Universität Berlin
Institute of Geographical Sciences, Physical Geography
Malteserstraße 74–100
12249 Berlin, Germany

E-Mail: jan.krause@fu-berlin.de

Rüdiger Krause

from 1987 to 2005 conservator at the Cultural Heritage Department of Baden-Württemberg, since 2005 Professor for Prehistory at the Johann Wolfgang Goethe-Universität Frankfurt am Main. Main research interests: Mining archaeology, European prehistory and the Bronze Age in Europe.

Prof. Dr. Rüdiger Krause
Johann Wolfgang Goethe-Universität
Institut für Archäologische Wissenschaften
Abt. III: Vor- und Frühgeschichte
Norbert-Wollheim-Platz 1
60629 Frankfurt am Main, Germany

E-Mail: r.krause@em.uni-frankfurt.de

Alexandru Szentmiklosi

since 1996 museographer and archaeologist at the Museum of Banat and since 2007 head of the Archaeological Department. In 2009, he obtained his PhD and the position of senior researcher. Main subjects of interest and research: Late Bronze Age fortifications, Cruceni-Belegiš Culture, prehistoric metallurgy.

Dr. Alexandru Szentmiklosi
Muzeul Banatului Timişoara
Piaţa Huniade, nr. 1, Castelul Huniazilor
300002 Timişoara, Romania

E-Mail: szentmiklosi@yahoo.com

Brigitta Schütt

since 2002 Professor, Institute of Geographical Sciences, Freie Universität Berlin, and since 2010 Vice President for Research at the Freie Universität Berlin. Research interests: Past and present soil erosion, Late-Quaternary paleoenvironments, paleohydrology, past and present morphodynamics, drylands, watershed management.

Prof. Dr. Brigitta Schütt
Freie Universität Berlin
Institute of Geographical Sciences, Physical Geography
Malteserstr. 74–100
12249 Berlin, Germany

E-Mail: brigitta.schuett@fu-berlin.de